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RAS GEMSAH & GEBEL ZEIT

REPORT

ON THEIR

GEOLOGY & PETROLEUM

BY

L. H. MITCHELL
GEOLOGIST AND ENGINEER.

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REPORT

Notes on the Geology of the Regions of Ras Gemsah and Gebel Zeit, together with a summary of facts, inferences, and conclusions, referring to the Question of Petroleum in its relations to that Geology; the result of a reconnaissance, made during a period of time extending, from the 22nd of April to the 10th August 1886.

To His Excellency

ABDUL RAHMAN PASHA ROUSHDY

Minister of Public Works

G.S.C.
W. J. Hussey
9-18-39

PREFACE

In the way of preface to this Report, which may be considered definite, in contradistinction to a hastily written preliminary one submitted under date of August 28th 1886, it is only necessary to say, as regards the geological part of it, that it is not as perfect as I could have wished.

However satisfied I may be, in a general sense, with the results of this portion of my labour, I can only regret that time and circumstance did not permit me to work up the details of the geology of the region in a more definite and complete manner.

As to that part particularly devoted to the question of petroleum, I await, in confidence, for practical researches to decide as to the correctness of my inferences and conclusions.

A very large collection of specimens made during the course of my reconnaissance, illustrates the geology of the region and, at the same time, bears witness to the various kinds of indications of petroleum that were discovered.

The maps accompanying this Report show to the eye, in plan and sections, what I have endeavoured, I trust, with at least a

small measure of success, to render comprehensible by means of the pen.

As to the classification of fossils and shells, I am indebted to the courtesy and eminent ability of Professor Carl Mayer-Eymar of Zurich; for most valuable geological information to Dr G. Schweinfurth; for excellent topographical work in the field to my assistant H. Huber, Engineer of Land Surveys; and finally, to Lieut. Dietmann R. A. Austrian Army, for artistic work.

The frontispiece *(see plate 1)* is a landscape view of Wady Melaha, with what I have termed the Limestone chain in the foreground, and the mountains of the Watershed range in the distance.

Plate 1

WADY – MELAHA

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INTRODUCTION

In beginning this Report, I may merely say, that the result of my reconnaissance, can by no means be looked upon as a geological survey of the regions traversed.

The objective point of the research was simply to determine the relation existing between the geology of the localities where petroleum was known to exist, to wit: Ras Gemsah and Gebel Zeit, and that of the surrounding country; in other words, to define, in so far as possible, the limits of the region or belt of territory within which practical researches for petroleum might have a fair chance of being rewarded with success, — that is to say, a delimitation of the petroleum zone. The geological facts arrived at may, therefore, be looked upon as simply incidental to this research. An exhaustive survey of the territory traversed would require the labour, rather of years, than months.

To what extent I may have succeeded in accomplishing the purposes of the mission entrusted to my care, I leave for those who study this Report, with its accompanying maps, to judge.

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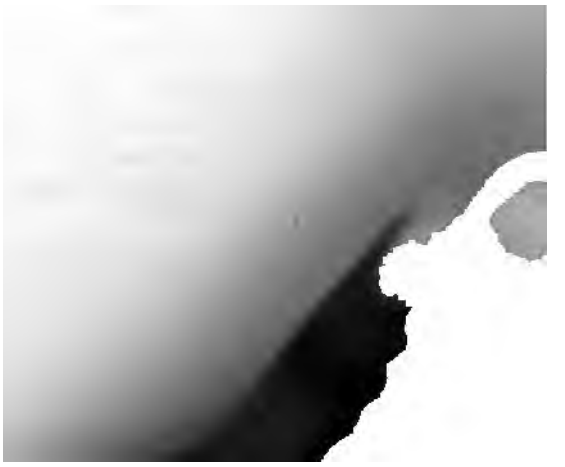

REPORT

I. — Region Explored.

The region covered by my reconnaissance is embraced, substantially, between parallels 27° 10′ and 28° 21′ North, and meridians 32′ 50° and 34° 00′ East; in other words, from the islands of Jifatin and Ras Abou Mingarh, southeasterly, to Gebel, and Ras Gharib, northwesterly; and from the islands of Shadwan and Jubal on the east, to the Watershed range of Gebels Gattar, Belih, Dokhan, Harbra, Mongoul, and Dara, on the west : this range separating the waters of the Nile basin from those of the Red Sea.

It was my original intention to have traversed the entire region of country between the Watershed range and the sea, from the island of Safajah, southeasterly, to Zafarana, northwesterly; from the fact that, at the first of these points, the Watershed range almost reaches the Red Sea, and at the second, very nearly touches the Gulf of Suez : thus the sea and the eruptive and metamorphic rocks of the Watershed range would have afforded, as regards the object in view, natural limits to my field of research. Loss of time, however, the natural result of intense midsummer heats, together with scarcity of water and unforseen difficulties to be contended against, compelled me, in the end, to forego two proposed trips; one to cover the region from Abou Mingarh to the Watershed range opposite the island of Safajah, the other to explore the plain betwen Ras Gharib and Zafarana.

In view of the fact that it may be read by many who are, perhaps, not familiar with the subject, I have thought proper, for the better understanding of it, to append a table, illustrating, in their order of sequence as regards time, the relative positions and consequent relative depths and ages of the rocks of the various Geological epochs, periods, and series, as referred to those of the Recent period and to each other.

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The topographical features of these unexplored parts are, however, so similar to those of the regions through which my reconnaissance extended, that one may safely assume them to be, on the whole, geologically the same.

II. — Physical Geography.

The present physical geography of the region bears the stamp of its past geological history, which clearly consists of alternating chapters of subsidences of the land beneath the level of the sea, followed by the deposition of the material which to day is seen in the form of strata or beds of sedimentary rocks; of elevations of the land above the level of the sea, followed by the disintegration of some of these strata, and the denudation of others; of eruptions or intrusions of granitic, syenitic, porphyritic, and greenstone masses forming dikes, plateaus, and mountain chains, followed to a greater or less degree by their disintegration, erosion, and decomposition.

As a result of this complexity of causes, working, each in its own way and time, there is now presented to the eye a relief form of land, simple in composition, bold in outline, and striking in effect.

Standing on the summit of Ras Gemsah by the sea, and gradually sweeping the horizon with the eye from south to west, and thence to the northwest, one traces, with scarcely a break in its visible continuity, the great Watershed range for a distance of over one hundred miles, that is to say, from nearly opposite the island of Safajah in the south, to Gebel Gharib in the northwest. The range lies at distances varying from fifteen to thirty miles from the sea, and has an average elevation above its level of about 3,000 feet, while some of its more prominent peaks such as Gebel Gharib, a view of which is seen on the opposite page, *(plate 2)* rise to heights ranging from 5,000, to over 6,000 feet.

– Plate 2 –

GEBEL GHARIB

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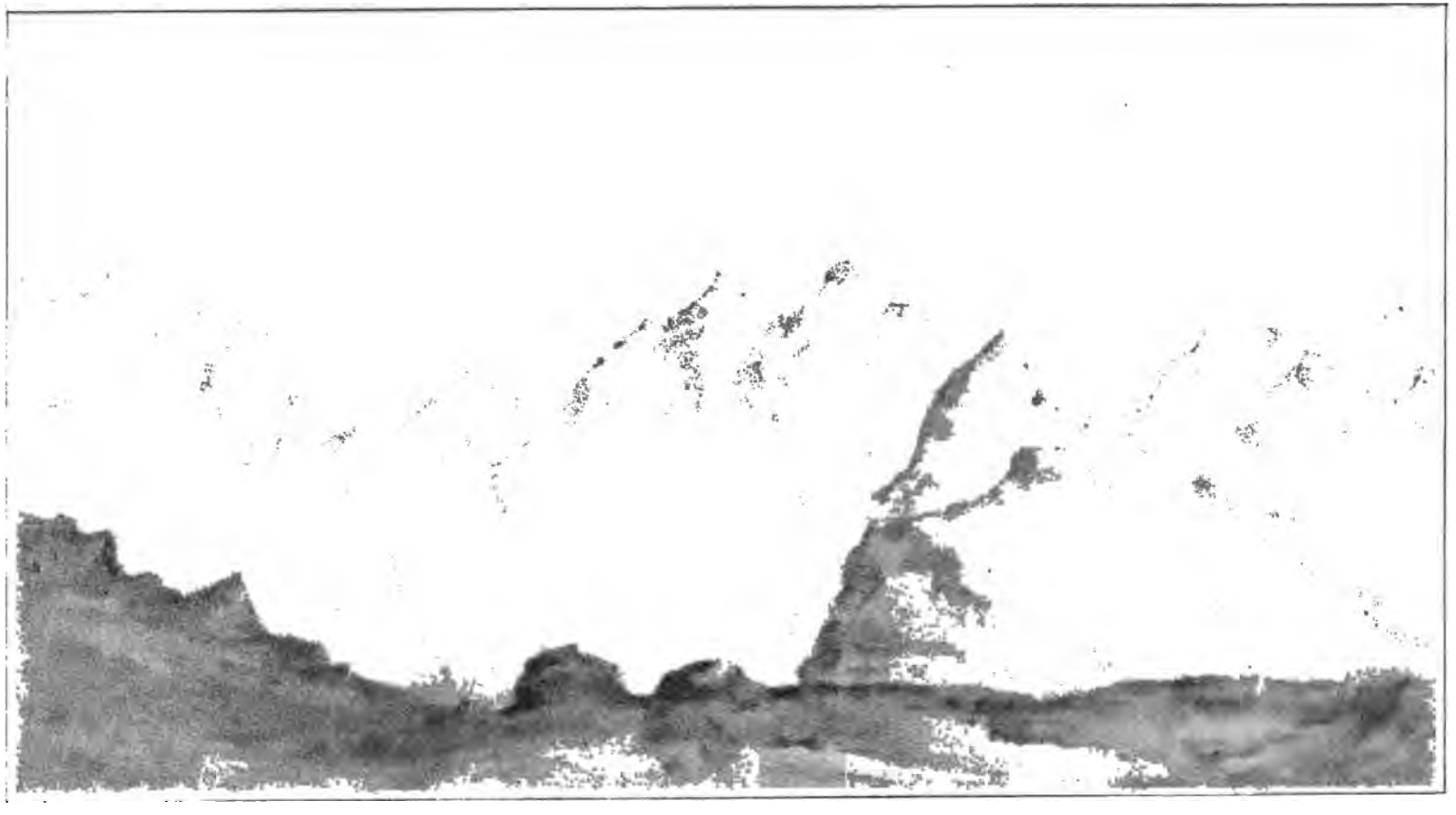
- Plate 2 -



GEBEL GHARIB

In the foreground, westerly, only a few miles from the sea, is seen a mountain chain named, after its principal summit, the Gebel Esh range. It is nearly parallel to the Watershed range with which it unites at its northwesterly extremity. The length of this chain is about forty miles, with an average width of about four, while in height, it varies from, say 700, to about 1,400 feet above the level of the sea. It is cut through, at several points, by valleys — ancient watercourses — connecting the Great plain with the sea.

Between these two mountain ranges of crystalline rocks is situated what I have denominated, for the sake of convenience, the Great plain. In length, it may be considered as extending from the southeasterly extremity of the Gebel Esh range by Abou Shaar to the point where this chain unites with the Watershed range. On account of the Gebel Esh range in the foreground this plain is not visible from the heights of Gemsah.

It is in general undulating in its character, with here and there low ridges and hills — remains of sedimentary strata that once covered it — rising above the general level. It has an average width between the two mountain chains of about fifteen miles, and an average height above the sea of about 600 feet.

In view of the tilting of its strata along the border of the Gebel Esh range, the disintegration and wearing away of the sedimentary rocks of this part of the plain have been effected in such a way as to leave intact a ridge or chain of picturesque hills of an average height of about 400 feet above the surrounding level, running parallel to, and about three miles from the Gebel Esh range, for a distance of quite thirty-five miles. Facing the Gebel Esh range, they are very abrupt. Southwesterly, they slope gradually down to the general level of the plain.

The broad, long valley between this chain of hills and the Gebel Esh range was clearly formed by the gradual wearing away, through ages of time, of the inclined strata of the plain along the line of their tilted edges next to the range.

The narrow belt of land between the Gebel Esh range and the sea, I have named the Coast plain, including also in this nomenclature those broader tracts of territory beyond the extremities of the Gebel Esh range stretching, respectively, from the sea to the Watershed mountains. It presents to the eye an undulating surface, interspersed, here and there, with ancient watercourses or broad valleys, with ridges and hills, and rises gradually, with varying degrees of inclination, from the coast to the base of the mountain chains along the line of which its elevation above the sea ranges from 77 feet at Bir Abou Shaar, to 1,245 feet at the foot of Gebel Gharib.

Aside from its Diluvial beds, seen, here and there on the coast line, its rocks, sedimentary in character, are of the same geological ages as those of the Great plain just described.

As an exceptional feature in the general topography of the Coast plain, there may be noted the isolated range of mountains known as the Zeit Hills, or Gebel Zeit. Viewed from the summit of Ras Gemsah, its dark peaks of eruptive rocks, contrasting strongly with the light colours of the sedimentary strata below, are seen in a northwesterly direction, about fifteen milles away, rising to an average height of 1,200 feet above the level of the sea. This chain of porphyry hills skirts the sea-shore for a distance of over fifteen miles and, whether viewed from sea or desert, constitutes one of the prominent landmarks of the region.

Another distinguishing feature in the Coast plain is the headland of Ras Gemsah itself. It rises 267 feet above the sea, from which it is seen as twin summits, — in the sunlight of almost a snowy whiteness, — separated from each other by a narrow gorge. The existence of this headland is probably due to the subterranean action of eruptive forces.

The other principal headlands of the Coast plain are Abou Mingarh and Abou Hurghada; the former rising 285 feet, and the latter about 200 above the level of the sea. They are situated opposite the islands of Jifatin, and consist of tilted

strata of sedimentary rocks dipping from the sea towards the southwest.

Among the islands off the coast, Shadwan, situated at the entrance of the strait of Jubal, is the most important. It is the largest, and in view of its position, of great significance in the navigation of the sea. It has an average height of about 800 feet, while its principal peak, near its southeasterly extremity, towers nearly 1,000 feet above the water's edge. The other islands noted on the accompanying map rise, at different points, to heights varying from 50 to 400 feet. With the exception of the greater portion of Shadwan, these islands are composed of Tertiary strata. They may, or may not, though their appearance generally indicates them to have risen gradually out of the sea.

The islands of North Gaysoom, South Gaysoom, Towilah and Jubal, were presumably at one time united together as a single island, the gradual wear of the sea having divided it into its present isolated parts. The islands of Great, and Little Jifatin, it may be presumed, came as one from the sea.

With this general description of the physical geography of the regions surveyed, I will now, as intimately connected with the same, refer to —

The Natural Water Supply. — This is always limited in quantity, and at the present moment, after a lapse of four seasons without rain fall, is unusually so. Indeed, it is asserted by the Bedouins that, unless a copious fall of rain should occur within the course of the next two years, it may be expected that the wells will become to a great extent exhausted.

The wells visited, and indicated on the map accompanying this Report, are as follows : — Mountain wells; Bir El-Gattar, Bir El-Dokhan or Badea, Bir El-Mongoul, Bir El-Dara, and Bir El-Gharib : — Plain wells ; Bir El-Malaha, Bir Abou Shaar, and Bir El-Nakhl.

Bir El-Gattar. — This well consists of a succession of pools of rain-water caught in the upper reaches and gorges of a wady or valley, cut in the massive granitic mountain chain known as Gebel Gattar. It is situated on the Nile side of the watershed, about three miles southeasterly from the Keneh route. There is at the present time a copious supply of clear pure water in these pools.

Bir El-Dokhan or Badea.— This well is situated on the Keneh route near an old fortified Roman station, at the foot of Gebel Dokhan, and was formed by excavating to a depth of from 12 to 15 feet in the detritus of the valley at the foot of the mountain. The water is the result of rainfall. It is very limited in quantity, and though somewhat brackish, is nevertheless fairly drinkable.

Bir El-Mongoul. — This well is situated at the foot of Gebel Mongoul. The water is obtained from a hole sunk in the porphyry of the mountain at the bottom of one of its ravines to a depth of eight or ten feet. It is clear and sweet, but, owing to the long lapse of time since a rainfall, it now exists only in limited quantity. A supply for an ordinary caravan of fifteen or twenty camels, would, at the present moment, practically exhaust the well for at least twenty four hours.

Bir El-Dara. — The site of this well is picturesque in the extreme. It is found in that part of the great granitic chain of the Watershed range, known as Gebel Dara, nearly sixteen hundred feet above the sea, and is arrived at only by climbing well on toward a thousand feet through a narrow gorge up into the summit of the mountain, where one descends into, as it were, a sort of amphitheatre or basin formed by the intersection of three or four gorges. The rain, caught during a storm in one of these gorge, is collected in its cavities and given out in such a way as to form a beautiful pool, always in shade, at the bottom of the basin. The water is excellent, but is now

- Plate 3 -

BIR-EL-DARA

found only in a very small quantity. Enough cannot be obtained at any one time to supply a small caravan. The accompanying sketch *(see plate 3)* is a very faithful representation of this gorge, with the pool hidden behind the rocks at its foot.

Bir El-Gharib. — This well, always in the shade, is found in a sort of basin underneath or in a highly flesh-coloured feldspathic rock which fringes, at its base on the edge of the Coast plain, that part of the massive granitic chain just referred to, known as Gebel Gharib. It is supplied, by means of hidden channels, with rain-water from basins or gorges in the mountain, and furnishes an unfailing supply of the purest water for the flocks of sheep and caravans of camels belonging to the Bedouin tribes living, or coming within its reach. It is situated about 1,350 feet above the level of the sea — which, at this point, is hardly twenty miles away, — with the peaks of Gharib towering immediately above it to a height of about 4,000 feet.

Bir El-Melaha. — Of the plain wells, this only is situated in what I have denominated the Great plain. It is found 230 feet above the level of the sea in Wady Melaha, between the Limestone chain and the Gebel Esh range, very near to the latter. It consists of a shallow basin dug in the loose sand or earth resting upon the sandstone strata of the locality. This sandstone is more or less impregnated with mineral salts, as also other sedimentary strata bedded with it. The water which fills the basin is in considerable quantity, but so saline that it is not drinkable for man, and barely so for beast. It is more particularly drunk by camels that have become accustomed to it by long usage.

Bir Abou Shaar. — This well, situated about 77 feet above the level of the sea, is in the Coast plain close to the foot of the Gebel Esh range, and immediately under that part of it known as Gebel Abou Shaar. The water exists in tolerable quantity, is

very brackish, more or less charged with sulphuretted hydrogen and can be drunk only by camels.

Bir El-Nakhl. — This much frequented well is situated in the Coast plain at an elevation of 297 feet above, and about eight miles away, from the sea. It is an important camping place for caravans passing to and fro. It consists of a shallow basin dug in the sedimentary rock at the bottom of one of the valleys or ancient watercourses of the plain. It furnishes a copious supply of brackish water, not palatable, but, in case of need, fairly drinkable. The supply, like that of all the wells described, is the result simply of rainfall.

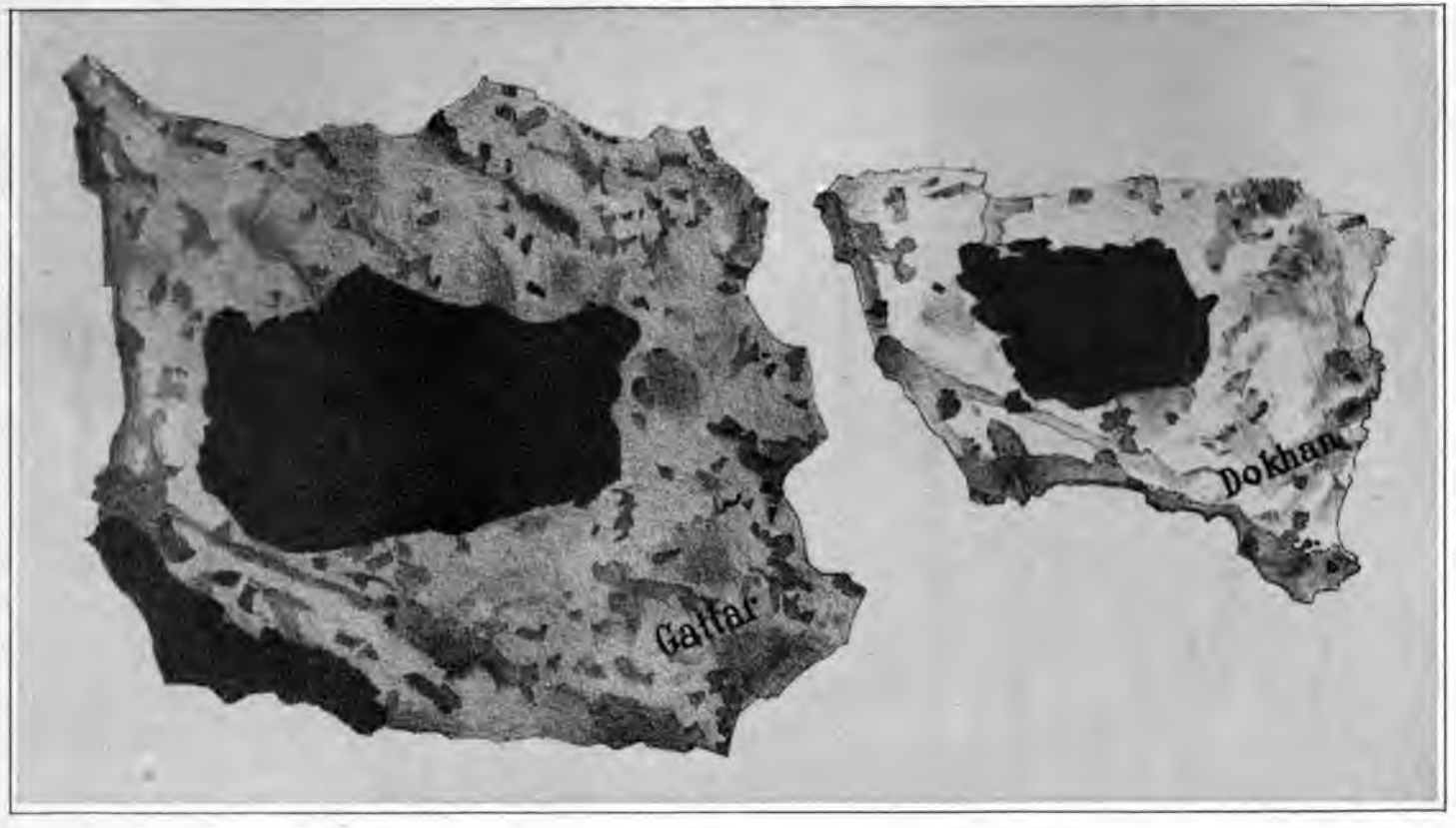
SYSTEMS OF ROCKS

I. — Eruptives and Metamorphics.

1. The Watershed Range. — The great Watershed range of crystalline rocks which, so to speak, forms the axis of all the later sedimentary formations deposited on its Nile and Red Sea sides, is made up, at the points where visited, principally of eruptive granites. Next in order of prominence come the porphyries while the least important part of all is played by the metamorphics which show themselves rarely, here and there, in the midst of the chains or fields of eruptives; they having been it appears, for the most part, absorbed by the intrusion of the latter.

Along the line of the Keneh route, the principal features noted — as one leaves the Great plain, ascends to and passes the watershed — are, on the right, Gebel Dokhan, and on the left, Gebels Belih and Gattar. Gebels Belih and Gattar, though

-Plate 4-



known under different names, are parts of one and the same granitic chain or field covering quite a large extent of territory in that part of the range.

Gebel Dokhan is separated from Gebels Belih and Gattar by a valley through which passes the Keneh route, and is composed of a granitic core capped and flanked, along the upper portions of its sides, with porphyry. With the wear of ages, the porphyry that once covered the lower parts of the mountain has largely fallen away and exposed the central core of granite.

In connection with this phenomenon I may note the fact of a prophyritic vein, from fifteen to twenty feet in width, discovered in the granite on the summit of one of the principal ridges of the mountain. This vein is situated in the longitudinal axis of the ridge, and can be traced with the eye well on towards the top of one of the highest peaks of the mountain where it disappears in the midst of the porphyry cap. I have considered this phenomenon worthy of note as pointing possibly, to the reason of the granite core being capped and sheathed, so to speak, in a mail of porphyry. Gebel Dokhan is the "*mons porphyrites*" of the Romans, the ruins of several of whose stations still exist near its base.

The granite of Gebel Dokhan, as also that of Gebels Belih and Gattar, is evidently eruptive in its origin. This is clearly proved to be the case by the fact that there are found, enclosed in it, fragments of nearly all sizes and forms of an old metamorphic system, the rocks of which must have existed at the time of the intrusion of the granite. The accompanying sketch *(see plate 4)* indicates, in section, two of these angular fragments enclosed, respectively, in the granite of Gebels Gattar and Dokhan.

The granite of Gebels Gattar and Belih is in some parts light grey, in others, a red orthoclase feldspar gives it a flesh-coloured appearence. In texture, it is of medium grain. In composition, the minerals, quartz and feldspar, are about evenly divided as to proportion, while its greenish black mica plays a very subordinate part.

The granite of Gebel Dokhan is coarse-grained; in colour, grey with a flesh-coloured tinge from an admixture of darkish red orthoclase feldspar. Of the minerals entering into its composition, feldspar is in the ascendency, its quartz and mica being in about even proportion.

The rocks in the valley between these two massive granitic chains or fields are composed of slates and greenstones. They are clearly part of an old metamorphic formation broken up and largely absorbed by the intrusion of the granitic masses. In evidence that a portion of this formation was originally sedimentary I may refer to the discovery of massive strata of highly indurated fine-grained, clay-slate. It is of a greenish grey, or blackish colour, and has its planes of cleavage fairly well defined. These slates are interstratified with the greenstones which are greatly in predominance. The beds of these rocks dip from the granite of Gebel Dokhan southeasterly, at an angle of about 20°, and were doubtless tilted by the intrusion of the latter. Their relation to each other and to the granite is indicated by the accompanying sketch *(see plate 5)* which shows the granite on the right, and the slate strata, between the greenstones, on the left.

Along the border of the Great plain, between it and the granite fields, large masses of syenite, quartz-porphyry, etc., were found. The feldspar of the syenite is a red orthoclase predominating greatly over its other minerals, quartz and hornblende. Although no definitive evidence therefrom was obtained it may be safely assumed that the syenite, eruptive in its origin, is younger than the grey granites. There is, however, legitimate proof that its origin dates from a point of time subsequent to the deposition of the cretaceous rocks, as evidenced by the subjoined sketch *(see plate 6)* showing a sandstone stratum of the Upper Cretaceous series tilted by, and resting upon it.

In addition to the above mentioned rocks, granitic, feldspathic and felsitic porphyries, either in vein or strata form, abound to a considerable extent.

Plate 5

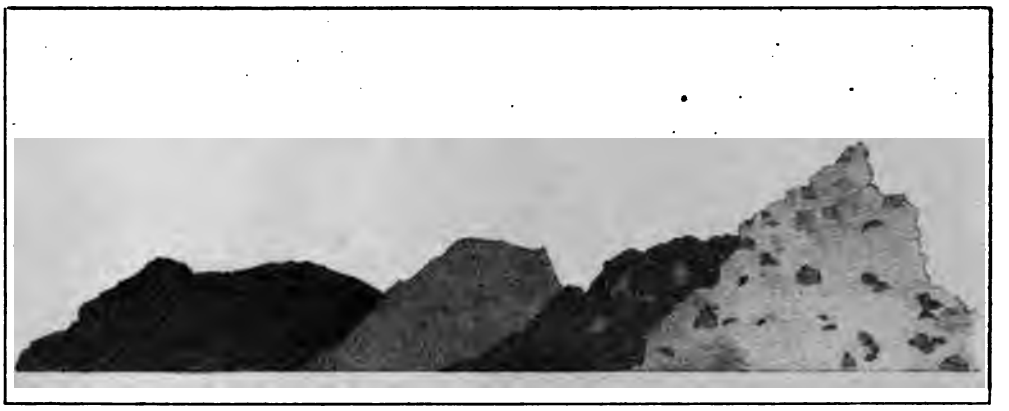
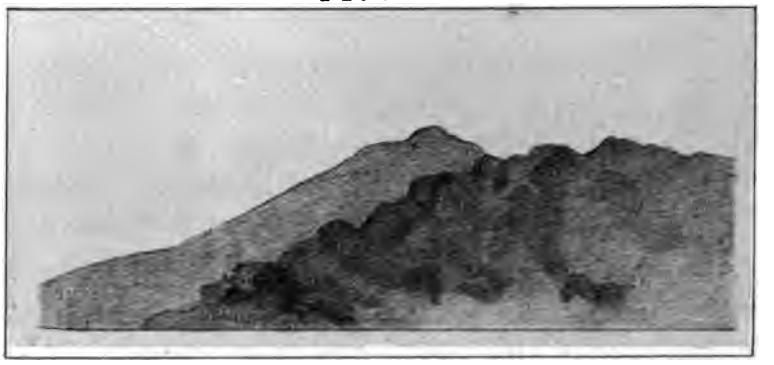


Plate 6



The quarries of red or purple porphyry, the "*porfido rosso antico*" of Italian Art, once worked largely by the Romans under the Emperors, are situated in the southwesterly parts of Gebel Dokhan, high up in one of its spurs. A winding road, about twenty feet in width, cut in the porphyry of the mountain side, leads to the quarries above. Great blocks of this highly prized purple porphyry were brought along this road, from the quarries in the mountain summit to the valley below, where, not far from one of their principal stations, they were hewn or chiselled into the various forms required for household, sculptural, ornamental, or architectural purposes. Some of these blocks, still to be seen in the midst of the debris of the valley, are several tons in weight. A moraine, so to speak, of porphyry debris or chips, ten or twelve feet in thickness, in the valley where the mountain road joins it, implies that this work must have been carried on for a great length of time. The granite of Gebel Dokhan was also quarried by the Romans for architectural purposes; the columns, capitals, entablatures, etc., of what was once a very beautiful temple in the valley, situated only a little distance from the ruins of the station referred to, having been hewn or cut from it.

As only a very short time could be given to a reconnaissance of the Watershed range, I did not succeed in making any discoveries that enable me to speak with any certainty, at all, as regards the comparative geological age of its rocks, other than that; firstly, the granite fields, the syenite, and some of the porphyries, are relatively younger than the metamorphics, of which the crystalline clay-slate heretofore referred to, is a remnant; and that; secondly, the syenite is younger than the sedimentary rocks of the Upper Cretaceous series. There can, however, be no question but that the metamorphics, as regards their age, fall far back within the Primary or Palæozoic epoch, with the probabilities in favour of their belonging to the rocks of the Cambrian, rather than to those of a later period of the epoch

Referring to the other points visited in the Watershed range, I may note the granite field of Gebel Marden; in other words, "mine mountain." The greater portion of the field consists of a grey granite, with a highly flesh-coloured tinge resulting from a large admixture of red orthoclase feldspar, going over, quite often, into a red orthoclase and hornblende rock. There are many very small veins of copper ore cutting the granite, while the surfaces of its fine seams are largely coated, in many places, with the carbonate of the metal. These veins and seams were greatly worked by the Romans. A half day, however, spent in looking over the locality, convinced me that the mines are too poor to have, at the present day, any practical value. The rocks between the granite fields of Gebels Marden and Dara consist, for the most part, of porphyry and porphyrites, among them a lavender-blue quartz-porphyry being particularly noticeable. Gebel Mongoul, in the central part of the locality, consists of a massive range of diabase-porphyrite.

With Gebel Dara commences a massive granitic chain continuing without a break to Gebel Gharib. Thence it sweeps on in a northwesterly direction towards Zafarana forming the westerly limit of the Coast plain. This rock may be termed a hornblende-granite. It is rather fine-grained, very compact, and tough. It is sometimes light, or ashy grey; at other times it is seen with a flesh-coloured tinge, the result of an admixture of a reddish-brown orthoclase feldspar. The greenish-black hornblende (amphibole) entering into its composition is very much subordinated in quantity to its quartz or feldspar; these latter minerals being divided in about an even proportion.

The granite of this chain is cut, here and there, with veins of trap like that of the field of Gebel Gattar, probably owing their origin to eruptions occurring during the same geological age. The basin or amphitheatre, heretofore referred to, in which is situated Bir El-Dara, is the indirect result of several of these veins meeting or cutting each other at different angles at nearly one and the same point. The gorges in the granite, and hence the

amphitheatre, were caused by the wear of the granitic mass having commenced along the lines of the veins of trap.

With the foregoing general notes on the rocks of the Watershed range, I will now refer to those of —

2. The Gebel Esh Range. — The different kinds of crystalline rocks that make up the Gebel Esh range proper conform largely, in their physical proporties and mineral combinations, to those of the Watershed range. One cannot, however, assign them to the same geological epoch or period, even although the chain made up of them now forms a spur of the Watershed range.

The predominating rock of the Gebel Esh range is porphyritic, and belongs to the family of greenstones. In some parts of the chain, its dark greenish-black ground is set with well developed crystals of feldspar, or hornblende, or both, and it becomes a true porphyry; in others, the rock, fine-grained and compact in texture, is devoid of any well defined crystalline forms. This rock, of igneous origin, largely predominates from Gebel Abou Shaar on to, and beyond the neighbourhood of Gebel Abou Hadt. With the exception of Gebel Abou Hadt, which is composed of syenitic rock, these porphyries form the highest peaks and summits of the range.

Subordinated to the porphyries are the granites and syenites, of which there are three independent fields that were particularly examined. One of these is situated along the edge of the Coast plain near the porphyry summit known as South-Saddle; another, cuts through the range from the Great, to the Coast plain; while the third, that of Gebel Abou Hadt, borders the Great plain. In addition to greenstones, granites, and syenites, quartz and feldspar porphyries, etc. etc., prevail to a greater or less extent.

The syenitic granite, or rather, syenite, of which the first field is made up, is very coarse-grained, and consists largely of a red orthoclase feldspar. Quartz and hornblende play an inferior part, while mica exists only in very small proportion.

A system of greenish-black hornblendic trap veins, or dikes, each about three feet in width cut through the syenite with a southwesterly strike. There was also observed a vein of pale violet coloured common quartz.

The accompanying sketch *(see plate 7)* shows the contact between the syenite and the adjoining porphyry.

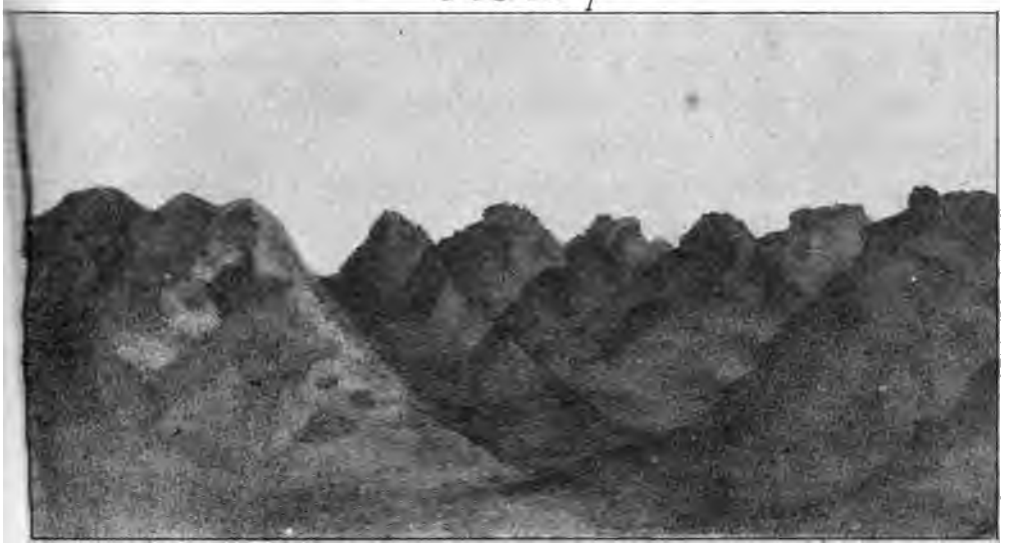
The line between the two is very sharply defined, at the same time very little metamorphism of the rocks on the contact plane has taken place — not enough, either on the one hand or the other, to enable one to decide as to their relative age. On other grounds, however, there are reasons for assuming the syenite to be the younger of the two.

The higher peaks of this field rise about seven hundred feet above the sea. One of them, on the edge of the Coast plain, is capped, and flanked on its seaward side, with a buff-coloured highly indurated limestone. The subjoined sketch *(see plate 8)* represents the relation existing between the syenite and the limestone at the point just referred to. The system of trap veins above noted are also seen cutting the syenite near its base.

The metamorphism or change that has been wrought in the the limestone, where in contact with the syenite, implies that it was elevated by the latter.

The granite of Wady Melaha has been worn through by atmospheric influences from the Great, to the Coast plain, forming a narrow valley through which passes one of the camel routes leading from Gemsah to Gebel Dokhan, and thence on to Keneh. Down this valley, for some distance, flows a tiny stream of salt water. Here and there it disappears in the sands of the valley; then reappears and forms a succession of pools, covered and surrounded with a luxurious vegetation of salt water grasses, plants, reeds, and shrubbery. This stream is the drainage water from the sedimentary rocks of the Great plain at and around Bir Melaha, where there is also a good deal of vegetation.

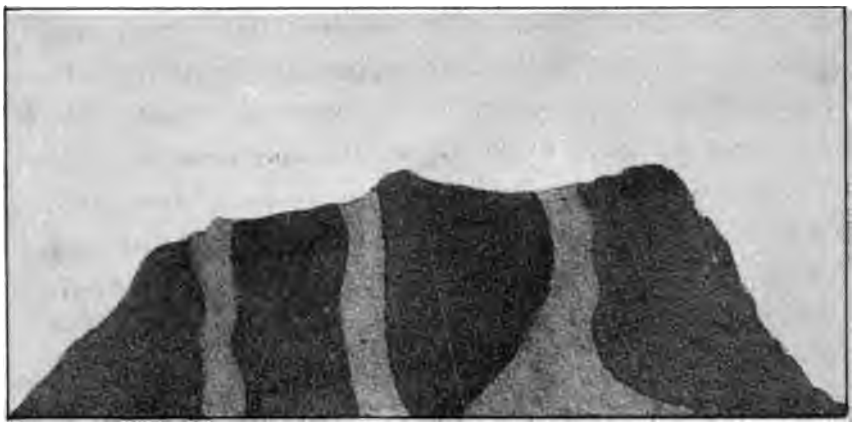
—Plate 7—



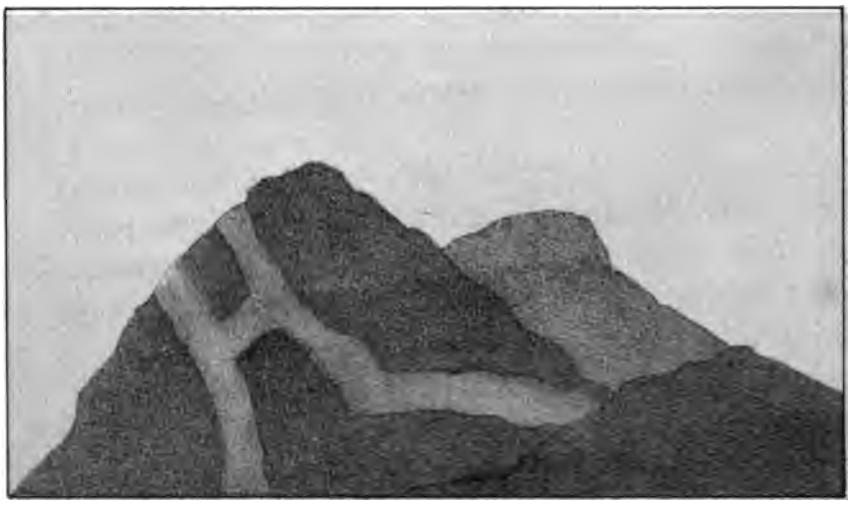
—Plate 8—

—Plate 9—

—Plate 10—



—Plate 11—



The granite is cut, here and there, with hornblendic trap veins, one of which, crossing the valley, proves clearly enough that the latter was formed simply by the erosive action of water. Another noteworthy fact is the detection of fragments of limestone clinging to a perpendicular surface of the granite on one of the sides of the valley near the point where it debouches into the Coast plain. They are apparently parts of a mass of limestone once enclosed in the granite. These fragments are very similar in their physical properties to one of the limestone strata flanking the granite on the edge of the Coast plain a few hundred feet away, and probably once formed part of it. This implies an intrusion of the granitic mass after the deposition of the limestone strata. The fact of these strata belonging to the Upper Miocene series of rocks gives, therefore, other things equal, a reason for an inference that the granite is the result of an intrusion occurring in the latter part of the Tertiary epoch. This granite is darkish-grey with a flesh-coloured tinge due to its brownish-red orthoclase. It is rather coarse-grained, with about an equal division of the three principal minerals, quartz, feldspar, and mica, entering into its composition. The following sketch (*see plate 9*) shows the limestone of the Coast plain resting at a sharp angle upon its side.

The metamorphism of the limestone, where in contact with the granite, bears out the view just expressed as regards the age of the latter.

The syenitic field of Abou Hadt lies in a direct line between Gemsah and Gebel Mongoul, along the edge of the Great plain. Abou Hadt, from which the field takes is name, is the principal peak, rising 1,365 feet above the level of the sea. This syenite is quite similar in colour, physical properties, and mineral composition, to that of the first field described. Positive evidence that it is comparatively younger than the porphyry surrounding it on three of its sides, is seen in the numerous wedge-shaped veins running from the principal mass into the former. The subjoined sketches (*see plates 10 and 11*) represent, in section, these syenitic veins penetrating the porphyry.

Another evidence of the comparative age of the syenite, as also the fact of its igneous origin, is seen in the scorification of the porphyry at many points where in contact with the syenite mass. No points of contact were observed between the syenite and the sedimentary rocks of the Great plain. The latter, however, dip southwesterly, from the syenite, at an angle of about 12°, indicating them to have been tilted by the intrusion of the syenitic mass. In this case, the syenite is, apparently, younger than the Upper Cretaceous rocks. By analogy it may be assumed to belong to the same geological period, as regards its origin, as the syenite of the field near South-Saddle as first described.

At some points examined, the relation existing between the crystalline rocks of the range and the sedimentaries of the plains is clearly defined; for instance, the contact rocks on the edge of the Coast plain, in front of Gebel Abou Hadt, show that, at that place, the limestones are younger than the porphyries the former having been deposited on the latter. This fact is very clearly demonstrated by the contact surface where the limestone is bedded directly on the crystalline rock, its under surface having taken the impression of the sharp angular prismoidal irregularities presented by the latter.

Again, between the syenitic field near South-Saddle and Gebel Abou Shaar, the range consists, for quite a distance, of a plateau of porphyry on the level surface of which is bedded a massive stratum of fossiliferous limestone belonging to the Upper Miocene series. Near its plane of contact with the porphyry, this limestone contains, in addition to its fossils, many angular fragments, of various sizes, of this porphyry upon which it rests; while at the same time it is entirely free from all signs of metamorphism or change resulting from the effects of heat or pressure. This could not naturally be the case were the porphyry the younger of the two. The following sketch (*see plate 12*) represents the limestone resting horizontally on the surface of the porphyry.

Plate 12

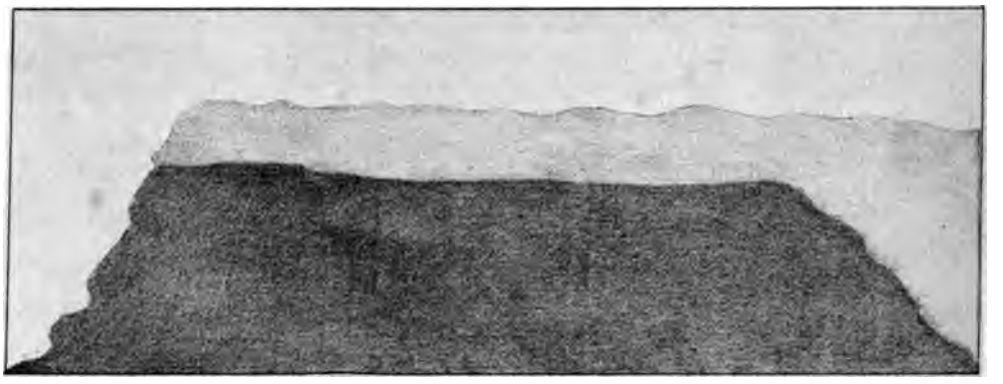


Plate 13

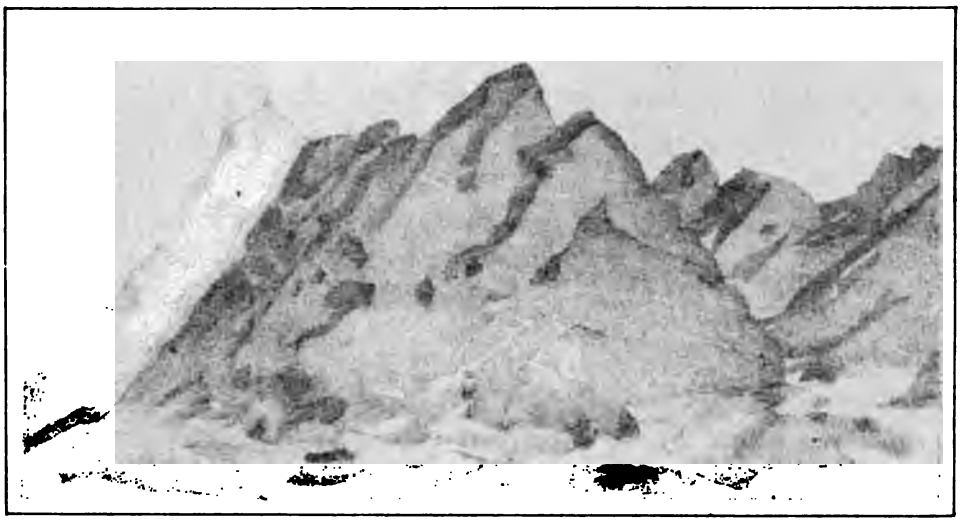
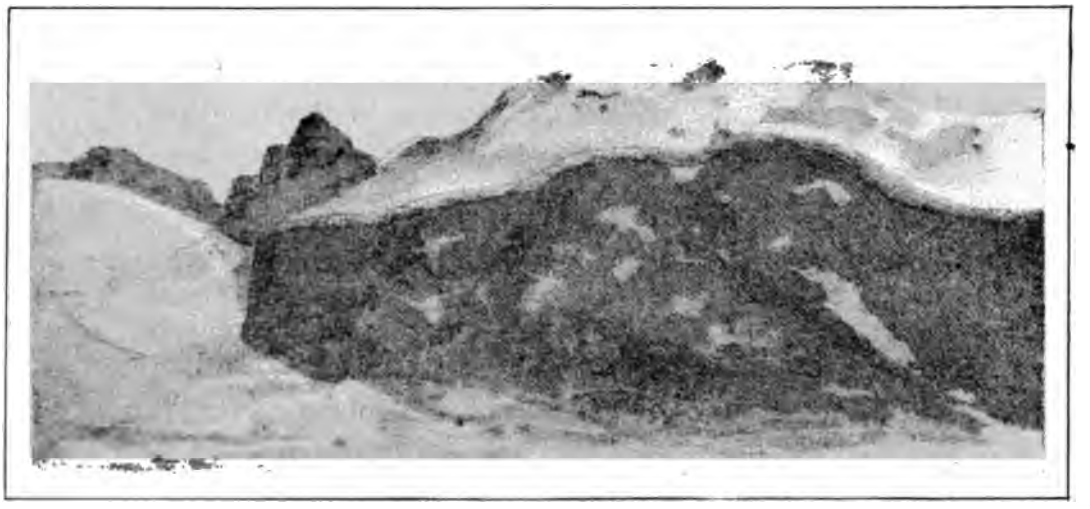


Plate 14



An examination of the range between the granite of Wady Melaha and Gebel Esh disclosed a narrow gorge on one side of which the limestone was seen resting on the porphyry at an angle of about 50°. Induration of the limestone and a contact conglomerate of calcareous flint, evidently the result of heat action, indicate the limestone to be relatively older than the porphyry and to have been tilted by it. The relation of these to each other is illustrated by the accompanying sketch (*see plate 13*).

On the opposite side of the gorge the limestone was found resting upon the irregular surface of the porphyry. Instead, however, of a sharp, well-defined line of demarcation between the two, as would naturally be the case had the limestone been deposited upon the porphyry, there was everywhere noted, along the plane of contact, the conglomerate referred to in connection with the foregoing sketch. The following illustration (*see plate 14*) shows the limestone capping the porphyry with the conglomerate band between.

That portion of the Gebel Esh range known as Gebel Abou Shaar consists of an elevated plateau of highly indurated fossiliferous limestone. Along its face, fronting the Coast plain, its strata are inclined at an angle of about 50° towards the sea, while, on the level surface of the plateau above, they are at some points nearly or quite horizontal. It would, therefore, seem that the plateau is the result of an upheaval or uplifting of the limestone strata by means of the action of subterranean forces. I may also mention the fact that near Bir El Melaha, in the Great plain, southeasterly from the granite field, I found the sandstone of the Upper Cretaceous beds resting upon old crystalline rocks of the range, in such a way as to justify the conclusion that it was a case merely of deposition of the former upon the latter, and that consequently the Cretaceous, are here younger than the crystalline rocks.

The rocks of the Gebel Esh chain, from Abou Hadt on to the Watershed range, are principally hornblendic, porphyritic, feldspathic, and syenitic.

The foregoing notes on the relation of the different kinds of crystalline rocks of the Gebel Esh range to each other, and to the sedimentaries of the Great, and Coast plains, imply that the mountain chain is largely the result of eruptions or intrusions of igneous rocks that have taken place, from time to time, during a succession of different geological periods, and that, to a certain degree, they are relatively quite young, some of them it may be, dating their apperance well within the limit of the Tertiary epoch.

3. Gebel Zeit. — The southeasterly portions of the igneous rocks that form a chain heretofore referred to as skirting the sea for a distance of over fifteen miles, known as Gebel Zeit or the Zeit Hills, consist of hornblendic porphyry normally of a greenish-black colour, passing often into a mixture of hornblende and brownish-red orthoclase. The northwesterly part of the chain is granitic in its character. The rock in this locality may be described as a coarse-grained granite, rich in dark brownish red orthoclase, with a little quartz, and scattered crystals of mica. The intrusion of the rock of this chain tilted the Upper Miocene strata on both its land, and sea sides. Near the petroleum well a limestone stratum flanks the porphyry with a dip towards the sea of about 40 degrees. This limestone, of a light buff colour, is semi-crystalline and highly indurated from the effects of heat and pressure. Upon it are bedded diluvial sands, shells, coral limestone, porphyry debris, etc., with a gentle incline towards the sea of from 5 to 6 degrees. The accompanying sketch (*see plate 15*) indicates the structural relation of the different kinds of rocks to each other, and the position of the petroleum well.

It appears, therefore, from the foregoing, that the crystalline rocks of Gebel Zeit are younger than the Upper Miocene sedimentaries.

Plate 15

GEBEL ZEIT

Plate 16

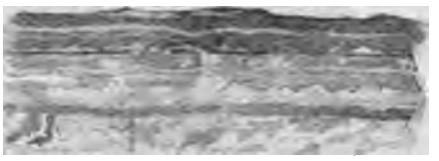


Plate 17

4. Ras Gemsah. – A very interesting feature of this promontory, is the fact of the metamorphism of the greater part of the southerly one of the two summits forming its extreme end, where the original limestone strata have been transformed by means of chemical changes into gypsum. Other noteworthy facts, are the dislocated, uplifted, and tilted condition of the strata of the two summits, the induration of the limestone of the northerly one, the threads, veins, nests and coatings of sulphur, largely intermixed in many places with the gypsum, and finally, the presence of sulphuretted hydrogen in a pool of water in one of the galleries or pits of the old sulphur mine.

These facts which will be alluded to further on, are, it seems to me, to be accounted for only on the hypothesis of the intrusion into the earth's crust below, of igneous rocks, which have not thus far been exposed by the wearing away of the upheaved strata, resting upon and above them. There is of course no means of fixing exactly the date of the intrusion of the presumed igneous mass concealed beneath.

The accompanying ideal sketches (*see plates 16 and 17*) illustrate, in a general way, the supposed relation existing between the presumed igneous mass below, and the uplifted sedimentary beds; the one on the left indicating the horizontal limestone strata previous to the supposed intrusion of igneous rocks, while that on the right, shows this igneous core with the upheaved, fissured, and tilted limestone beds transformed, as heretofore pointed out, into gypsum.

5. The Island of Shadwan. — About two-thirds of the island of Shadwan, southeasterly, consist for the most part of a granitic mass of rocks rising from 700, to nearly 1,000 feet above the level of the sea.

At the points where visited, the foreshore is made up of sedimentary rocks, composed principally of gypsum and limestone belonging to the Upper Miocene series; while, here and there, fields or beds of

the same, many feet in thickness, still flank the granitic core high up its slopes. This granite is a coarse-grained grey, very compact and tough. Near the centre of the island, it contains many fragmentary enclosures, large and small, of a fine-grained greyish black granite, which, on weathering, goes over into a proper gneiss or gneissoid granite. In some places these two granites present the appearance, almost, of interstratification, as illustrated in the accompanying sketch, (*see plate 18*) where they are in contact with limestone on the left. From other points of view, the dark granite appears to form veins in the grey, an instance of which is given in the subjoined illustration (*see plate 19*).

Another combination, in strata form, of these two kinds of granite was seen in a ridge sloping gradually towards the sea on the southwesterly side of the island, a view of which is shown in the following sketch (*see plate 20 on next page*).

As regards their structural relation to each other, it may be observed that there exists almost a perfect parallel between these two granites, on the one hand, and the coarse grey granite of Gebel Dokhan with its enclosed fragments, and, in some places, apparent interstratification on the other.

Further on, toward the southeasterly end of the island, the gneissoid rock seems to have disappeared. Two or three veins or dikes of greenstone trap were noted, at different points, cutting the granite.

The accompanying sketch (*see plate 21 on next page*) represents the granite in the southeasterly part of the island just referred to cut by a massive trap vein fifteen or twenty feet in width. Above are bedded sedimentary strata; first one, of clay or marl; then, a highly indurated layer of limestone; and finally, over all, are seen massive deposits of gypsum.

The trap dike evidently existed anterior to the deposition of the sedimentary strata upon the granite. The relations of the different parts of the complex to each other point, therefore, to

Plate 18

Plate 19

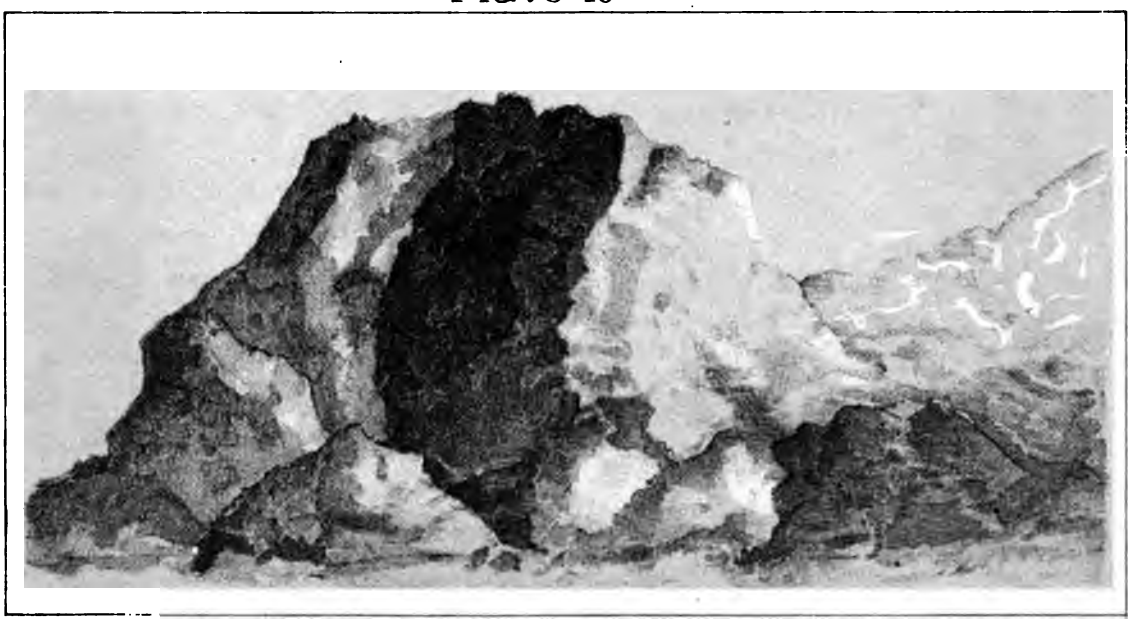
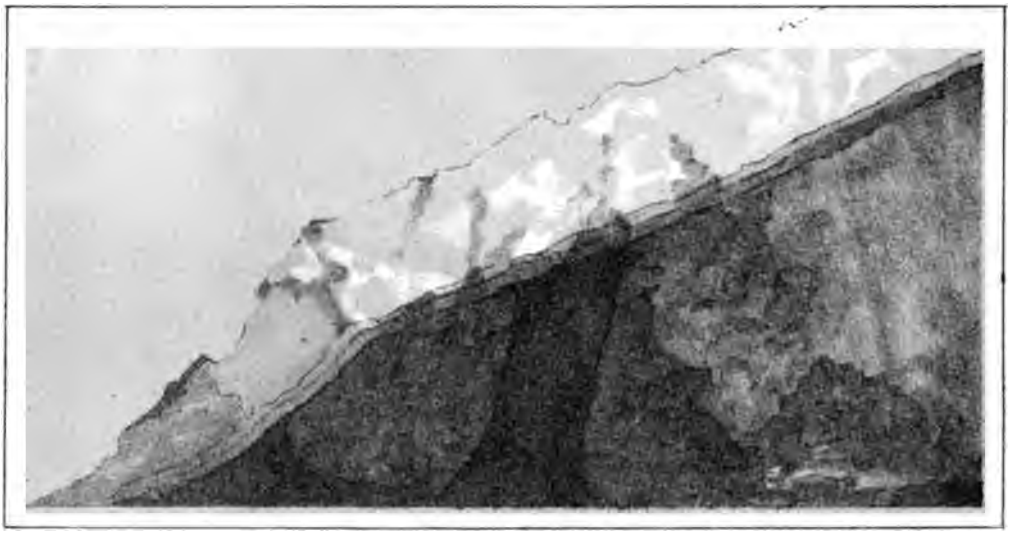


Plate 20

Plate 21



the fact, not of eruption or intrusion of the granite, but of an elevation of the entire mass, as a unit, out of the sea.

The deposition upon it of the Upper Miocene rocks fixes one limit, at least, as regards the date of origin of the granite; namely, that it is older than the rocks bedded upon it. Their general appearance, structural and otherwise, together with the parallel referred to, lead me to infer that the granites of this island are as old, at least, as those of the Watershed range. That they came out of the sea during the latest of the Tertiary periods is evidenced by the Pliocene strata of the northwesterly part of the Island which must have come up with them. With the foregoing notes on the crystalline and metamorphic rocks of the region explored, in the nature of the case fragmentary, I now pass to a review of the sedimentaries.

II. — The Sedimentary Rocks.

The sedimentary rocks of the region explored belong to the Cretaceous, Miocene, Pliocene, and Diluvial periods; and consequently to the Secondary, Tertiary and Post Tertiary epochs. Commencing in the order of the oldest, I will first describe those that were deposited during the Cretaceous period, and which fall within the limits of —

1. The Upper Cretaceous Series. — Within the area surveyed, this series of aqueous rocks was found exposed, in the Great plain, along the southwesterly side of the Gebel Esh range, from the neighbourhood of South-Saddle on to where the chain unites with the Watershed range near Gebel Dara; as also on the opposite side of the plain in the locality of Gebel Mongoul. A patch of it was also discovered in Wady Belih, on the southwesterly edge of

the plain, close to the crystalline rocks of the Watershed range. Its beds would probably have been found exposed at many, or all, points along the southwesterly side of the plain from the region of Gebel Dokhan to Gebel Mongoul had time permitted me to traverse that edge of it in its entire length.

In the Coast plain, this series was found to extend along the side next to the Watershed range from opposite Gebel Dara to Gebel Gharib. A reference to the accompanying map will show, within approximate limits, the surface area covered by the different beds of the series.

As has been hitherto remarked, it was the upheaval of these Upper Cretaceous beds along the line of the Gebel Esh range in the Great plain, and the subsequent wearing away of them along the line of their tilted edges, that originated the range of hills which I have named the Limestone chain. Along this chain the beds of the series dip southwesterly at angles varying from 10 to 15 degrees; while, on the side of the plain next to the Watershed range, they are tilted in an opposite direction; as for instance, in the neighbourhood of Gebel Mongoul where they dip at an angle of from 75 to 80 degrees northeasterly.

It may at once be inferred that the Cretaceous beds, underlying those of the Upper Miocene, form, as it were, a sort of basin between these two mountain ranges, and embrace, in their lateral extension, the entire area of the plain.

Where exposed along the foot of the Watershed range in the Coast plain, the strata of the series dip, as for instance in the neighbourhood of Gebel Dara, at an angle of from 75 to 80 degrees northwesterly. It may therefore by assumed that, throughout the whole extent of the plain, they underlie the beds of the Upper Miocene series which were deposited directly upon them. The tilting of the beds of the series is clearly due to the intrusion of masses of crystalline rocks in the lines of the two mountain chains.

Where most exposed to view, as regards depth, as for example at Bir El Melaha and Wady Dhib, these beds show an aggregate thickness, in the former locality, of about 500, and, in the latter of nearly or quite 700 feet. The absolute thickness of the series can, of course, only be known by finding the geological horizon or plane of demarcation between it and the group, whatever its age, lying next below.

The rocks which make up this series vary considerably in their lateral extension as regards some of the beds; those composing others remain constant throughout the entire exposed area.

In the way of general description, I may say that the lowest rocks exposed,* consist of massive sandstone strata found in those parts of the Cretaceous area which border on the crystalline rocks of the Watershed, and Gebel Esh ranges. They dip, at all points, underneath the other beds of the series. Along the border of the Watershed range, from Gebel Mongoul to Gebel Ghareb, these sandstone strata are very much exposed to view, having been tilted, together with their overlying beds, as heretofore remarked, by the intrusion of the crystalline rocks, to an angle of from 75 to 80 degrees. This sandstone is, here, in its normal condition, of a light grey colour. It is composed of sand particles cemented with carbonate of lime. In texture, it is normally very friable. It has, however, in many parts, been so exposed to the effects of heat and pressure due to the intrusion of eruptive rocks as to present the appearance almost of a true quartzite.

The character of the sandstone exposed along the line of the Gebel Esh range, is in general, the same as that just described. As along the Watershed range, so here, in many places, it has been greatly affected by the influence of heat and pressure; likewise, the result of the intrusion of eruptive rocks. It is also seen, in some places, in a great variety of colours, calling to mind the "*Buntsandstein*" of Germany.

* See sectional view opposite page 26.

Upon these sandstone strata are superimposed, in some places, tolerably thick beds of light, or dark yellowish brown limestone; as for instance in Wady Dhib, between the Limestone chain and Gebel Abou Hadt.

Above these beds, and underneath the great marl deposits, are found, in varying degrees of development in different parts of the area, sandstone, silicious limestone, clay, and shale. There are also seen, in connection with these beds, ferruginous marls and limestones, clays, sandstones, etc.; sometimes in very thin layers, of a thickness even of only a few inches, interchanging with each other in various ways and in quick succession.

On the top of this group of complex, alternating layers or strata, are deposited massive beds of marl in whitish, light buff, drab, and reddish-brown colours. Sometimes the strata appear of uniform colour; then, again, they are striped in narrow alternating bands of, say, buff and brown. At some points these marls appear to have been developed to a thickness of at least 200 feet. Between the marls and the massive flint and limestone strata that form the upper group of the series, are found, here and there, beds of impure chalk, or chalk-marl, perhaps it might be called. It is of a light buff colour, and possesses the physical properties of a true chalk.

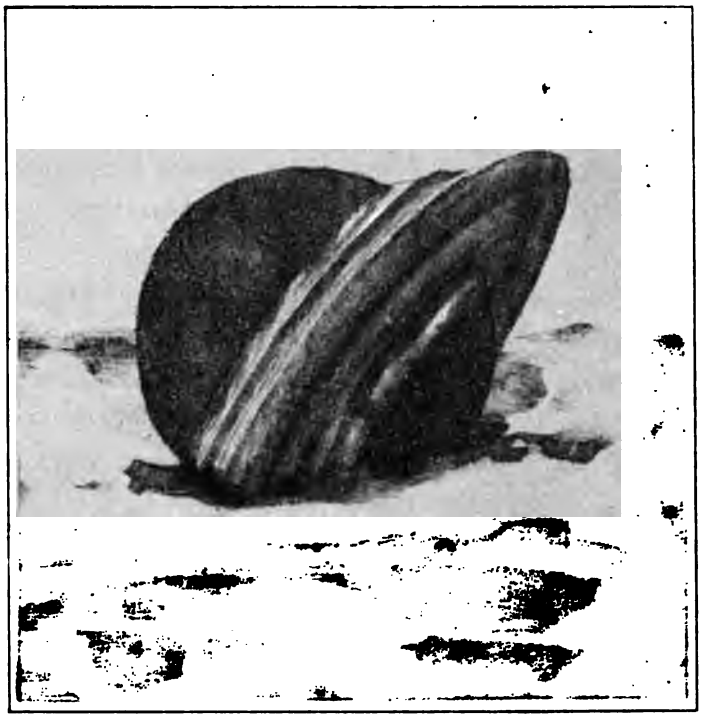
The uppermost group of rocks in the series consists of alternating layers or strata of white limestone, reddish-brown or drab coloured limestone in the form of disk-like concretions, grayish-black flint, and grey calcareous flint concretions.

The following sketch, from nature, (*see plate 22*) illustrates this uppermost group as seen in a cross section of the Limestone chain in Wady Dhib.

The layers or beds of flint vary in thickness from less than one inch to over two feet, corresponding changes occurring in the thickness of the limestone strata. Interstratified with these beds of limestone and flint are also found occasional layers of greys calcareous flint concretions of from a few inches, to a foot and a half or two feet in thickness; while a fourth element entering

Plate 22

Plate 28



into the complex is the interpolation of the layers or beds of disks above referred to. These disks vary, in form, from oval to round, and in size from, say, six inches, to three feet and a half, or four feet, in their long diameter.

The normal of their short diameter is about one half that of their long. It varies, however, to such a degree that the disks run through all the changes of form, from flat to round. They form beds between, and parallel to the layers of flint and planes of stratification. The accompanying sketch (*see plate 23*) shows one of these disks, about four feet in its long diameter, and two feet in its short, with some rings of flint passing round its outer edge. It is represented as seen lying in the desert sand on the spot where it fell from its original place in the strata above.

These disks contain a small percentage of silicate of iron. They are very compact, hard, brittle and heavy, and possess a resistance to decomposition under atmospheric influences nearly or quite as great as that of flint. There are indications that these layers or beds of disks consist, in reality, of the original limestone strata transformed into these concretions through processes of nature, either physical, or chemical, or both. In evidence of the above opinion, I may cite the fact of a disk-layer observed, passing gradually over, in its lateral extension, into a limestone stratum; also the bulging of originally parallel flint layers to make room for one of these disks, which appeared to require more space than that of the original limestone stratum; then again, the rings of flint encircling the disk represented above; and finally, one of these small round limestone concretions, two-thirds of which were buried within the flint.

This complex shows in some places, along what I have denominated the Limestone chain, a development of two hundred feet, or more, of thickness.

In order to present to the eye the relation to each other of the principal sedimentary strata that make up the Upper Cretaceous series just described, their order of superposition, dip, etc., as also

their relation to the crystalline rocks, respectively, of the Watershed and Gebel Esh ranges, I have given on the opposite page (*see plate 24*) a sectional view, of the beds of the series in the neighbourhood of Wady Dhib, between Gebel Mongoul in the former range, and Gebel Esh in the latter. *

With the foregoing review, in a general way, of the rocks of the Upper Cretaceous series I now pass to those of the Upper Miocene.

2. *The Upper Miocene Series.* — Throughout both plains, where explored, there does not appear to have been any deposition, whatever, of the rocks of the Eocene period, the beds of the Upper Miocene having been superimposed directly upon those of the Cretaceous. There are no data by means of which one can arrive at the original thickness of them for we have no standard of measure as regards the effect of the disintegrating and denuding forces that, perhaps for millions of years, have been wearing them down. All that can be said is, that the headlands of Abou Mingarh and Gemsah, the plateau of Abou Shaar, and the tilted strata of Gebel Zeit, exhibit, intact, thicknesses say, of from 250 to 350 feet. The rocks forming the different strata of this series, in contradistinction to those of the Upper Cretaceous, vary a good deal in their lateral extension, as also, in different localities, in their vertical development.

In the Great Plain, southwesterly from Wady Melaha, the hills and ridges rising out of the *detritus* that covers the region, exhibit, *in situ*, the remains of what were once extensive beds of brown, argillaceous and calcareous sandstone impregnated with mineral salts; brown marl, very fossiliferous; greenish coloured silicious

* The etching near the centre of the section indicates a patch of Upper Miocene rocks between the tilted ones of the Cretaceous series.

Plate 24

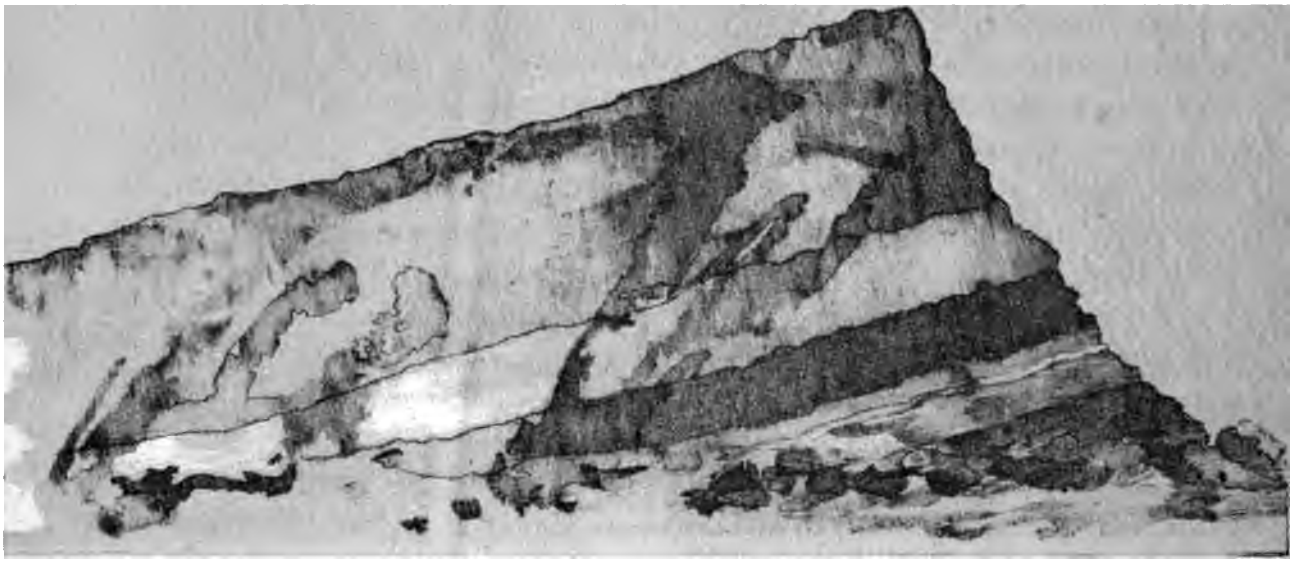
—SECTION—

21. Miles

GEBEL MONGOUL

GEBEL ABOU HADT

Plate 25



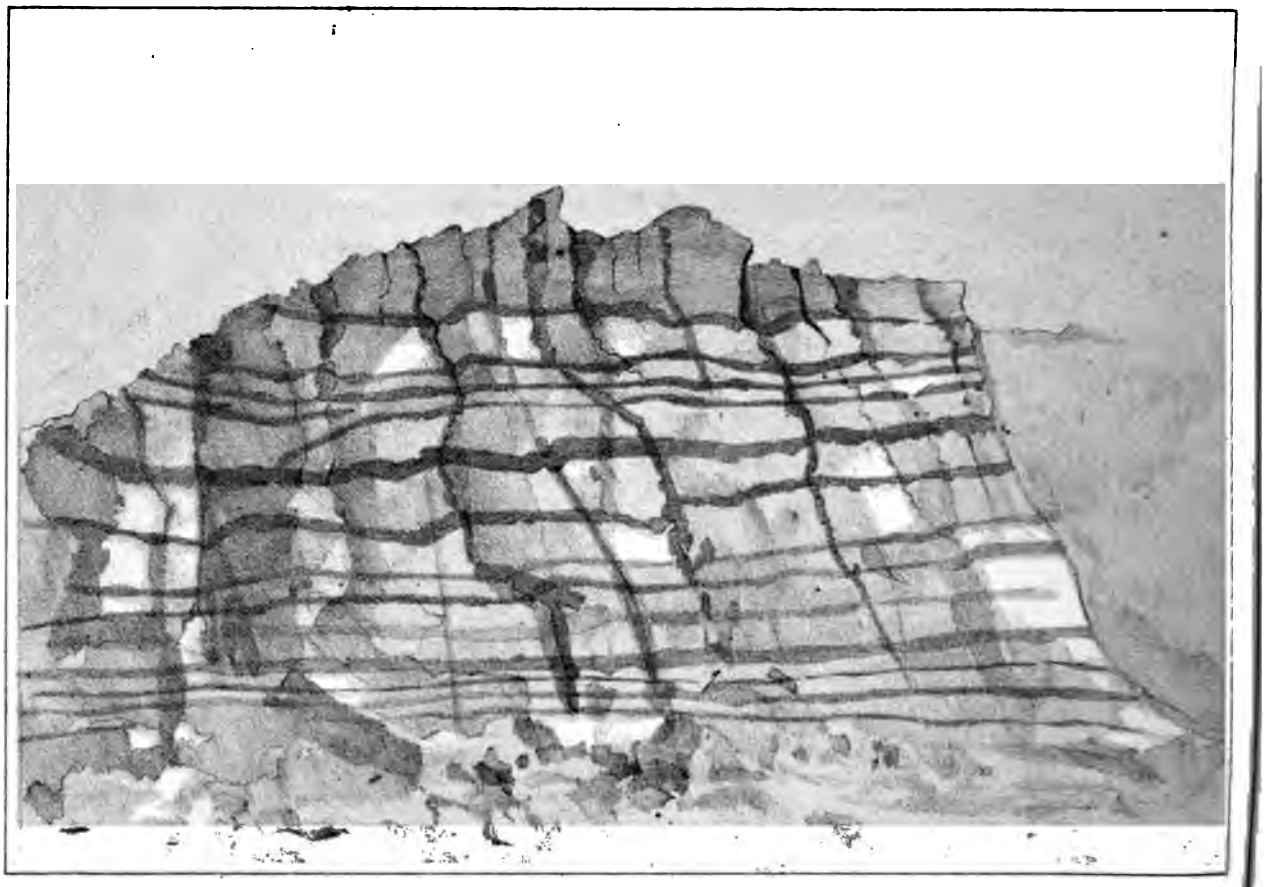
sandstones, friable, earthy and saline; drab-coloured clay and sand, very soft; light grey calcareous sandstone, very much segregated in grape-like bunches; sandy clay, striped in narrow bands of pink and drab; sandy marls, of an earthy nature and brownish-red colour; white compact fossiliferous limestone; and finally, near the sea, what appears to have been a bed, overlying all, or most of the others, of smoky-grey limestone, filled with fossils or shells of *Ostrea gigantea*.

Between this locality and Bir El-Nakhl, the remains of the Miocene series form massive chains of hills and ridges running in an easterly and westerly direction. They show a development, on a large scale, of soft, white limestone, gypsum, and yellowish-white, coarse, compact, fossiliferous limestone. Subordinated to these are beds of dark brown sandstone, marls, etc.

Between the Gulfs of Gemsah and Zeit, a series of ridges or hills, rising from the *detritus* of the plain, exposes to view massive strata of soft, white, tough limestone, the texture of which has the appearance of fish-roe. There is some silicious matter in its composition. It would seem to be a true Bryozoa. There are also seen strata of yellowish brown, calcareous sandstone (sand particles cemented with carbonate of lime) and pale yellow limestone beds largely made up of fossils; also shell-beds full of *Ostrea crassissima* and *Virleti*. The strata of these different beds dip at an angle of from 5 to 10 degrees in a northwesterly direction toward the sea. Westerly and southwesterly from the Gulf of Gemsah, the remnants of extensive areas of these fossils or shells are embedded in strata of calcareous and conglomerate sands.

The headland, Ras Gemsah, is now composed, for the most part, on the one hand, of beds separated by thin layers of clay or marl; of white gypsum containing veins, nests, and incrustations of sulphur, and, on the other hand, of massive strata of a buff-coloured, highly indurated semi-crystalline limestone. Of the two twin summits forming the headland facing the sea, the southerly one is composed mostly of gypsum; the northerly, of limestone.

Plate 26



The accompanying sketch (*see plate 26*) gives a front view of massive beds of gypsum separated from each other by thin layers of clay; the whole forming a frontage about 260 feet in height facing the Gulf of Gemsah, directly south of the petroleum wells.

In some places, the strata of this headland have been very much tilted and distorted; in others, they have retained, to a considerable extent, their normal position, as for instance, at the place represented in the sketch.

In reference to the existence of these massive strata of gypsum together with the sulphur found in connection with them, it may be remarked that they are, in this instance, simply secondary products in the laboratory of nature. The strata were originally limestone. On account of the presumed intrusion of the concealed igneous mass heretofore referred to, these strata were upheaved, distorted, fissured, and seamed. With the intrusion, came also an exhalation of sulphuretted hydrogen which permeated or suffused, by means of these fissures and seams, the upheaved limestone. The presence of this gas, brought on, through natural chemical reactions, the formation of sulphur and sulphuric acid the former of which was deposited in the form of threads, veins, nests, and incrustations, in the seams, fissures, and cavities of the disjointed strata, while the latter, displacing the carbonic acid of the limestone, united with the lime and formed sulphate of lime or gypsum. The transformation, in nature, of masses of limestone into gypsum, together with the deposition of sulphur by means of the above-mentioned process, is a well known geological fact. That the gypsum and sulphur of Gemsah owe their existence to the cause or causes referred to, is supported by the presence still, of sulphuretted hydrogen in the water standing in one of the old galleries of the sulphur mines near the sea, as also, more especially, by the discovery of masses of rock in the southerly or gypsum summit, the mineral composition of which, now consists of an intimate admixture of carbonate and sulphate of lime; in other words, rock in a state or condition of change or transition from limestone to gypsum.

I have referred to the well or spring called Bir Abou Shaar as being charged with sulphuretted hydrogen. This well is situated directly at the foot of the upheaved limestone strata which form the plateau, while close to it, in the plain, is a large field of gypsum. These facts lead me to conjecture that, in this instance also, the gypsum deposit is the result of geological activities and chemical reactions similar to those that must have taken place at Gemsah.

The beds tilted by the intrusion of the crystalline chain of Gebel Zeit, particularly on its landward side, consist, in so far as observed, chiefly of gypsum, limestone, sandstone and shell beds. On the crest of the ridge toward the southeasterly extremity of the chain and beyond the outcrop of its porphyry. I found a shell-bed of *Ostrea crassissima*, and strata of what I have referred to as possessing the characteristics of a Bryozoa limestone. These are probably the same strata, in their lateral extension, that were found between the Gulf of Zeit and Gemsah, already cited. I may also note the presence of this characteristic limestone on the Coast plain flanking the Gebel Esh range easterly from Gebel Abou Hadt. The fact is also particularly worthy of note of the discovery, at the extreme northwesterly end of the Zeit hills, about a mile beyond the last outcrop of the granite of which the igneous rock at this part of the range is composed, of massive strata of crystalline limestone between the gypsum crest and the sea; together with a bed of crystalline anhydrite between the gypsum and the limestone. These beds of limestone and gypsum appear to have been tilted into a nearly perpendicular position, the result, without doubt, of the intrusion of granitic masses thus far not exposed by the wearing away of overlying sedimentary strata.

The rocks of the islands of Jifatin, in contradistinction to those of the headland Abou Mingarh, opposite, a few miles away on the the coast, consist entirely of beds of limestone. They dip, at some points, a little to the west or northwest. The deepest lying beds on the two islands, are identical in their physical characteristics and are evidently different parts of the same strata. They are for

the most part pinkish white or drab-coloured, extremely hard, and semi-crystalline. The strata above these are composed of rocks more or less soft, white, or drab-coloured, and highly fossiliferous; indeed, some of the strata seem to be composed to a great extent of a mass of fossils, united with a little calcareous paste. Along the shore, on the westerly side of the island, there was observed, in some places, a stratum consisting of segregated particles, and small pebbles of limestone united with calcareous cement. This stratum takes the incline of the shore, is not fossiliferous, and, at first sight, might be taken for a coarse conglomerated sandstone. It was evidently formed, *in situ,* from the limestone sand and pebbles of the coast; and hence, it would seem, belongs to the Post Tertiary age.

3. The Upper Miocene and Pliocene Series. — I refer under this head, to the sedimentary strata of the islands of Shadwan, Jubal, etc., without any attempt to separate the beds of the two periods, Miocene and Pliocene, from each other.

As heretofore remarked, the northwesterly part of the island of Shadwan is composed of a series of sedimentary deposits rising to a height of nearly 800 feet above the level of the sea, with a slight westerly dip of from 5 to 10 degrees. These beds consist, below, of indurated buff-coloured limestone, some of them containing many fossils. A little above the sea, a deposit of clay, about three and a half feet thick, was found interstratified with these limestones. At some points this clay is quite saline; at others, it is found in the form of an impure kaoline. Superimposed, at one point, upon the limestone are seen beds of alabaster of a bluish-grey colour, which, in their upper layers, pass gradually over into a white, rather coarse-grained, friable gypsum. The gypsum is cut by many narrow precipitous ravines leading from its upper reaches to the sea. Here and there, crystals of gypsum (selenite) were seen in the seams of its "*fishnet*" surface, shimmering in the sunlight.

Upon the gypsum beds rest strata of soft, white limestone, more or less fossiliferous, with, now and then, thin layers of argillaceous limestone of a flesh coloured or greenish hue projecting like cornice work from the perpendicular front of white limestone towering above to a height of from 250 to 300 feet. These limestone strata possess the consistency, more or less, in some places, of beds of chalk. They form the central and highest ridge of the sedimentary portion of the island, and belong to the Pliocene period; while the indurated limestone under the gypsum beds is Upper Miocene. The accompanying sketch (*see plate 27*) indicates the method of association of these different kinds of beds with each other. It represents a portion of the southerly front of these sedimentary series.

Below is the indurated limestone more or less covered with a conglomerate of *detritus* from overlying beds; above, are the massive strata of soft, white, Pliocene limestone, while between the two are seen the gypsum deposits cut by ravines running down to the sea.

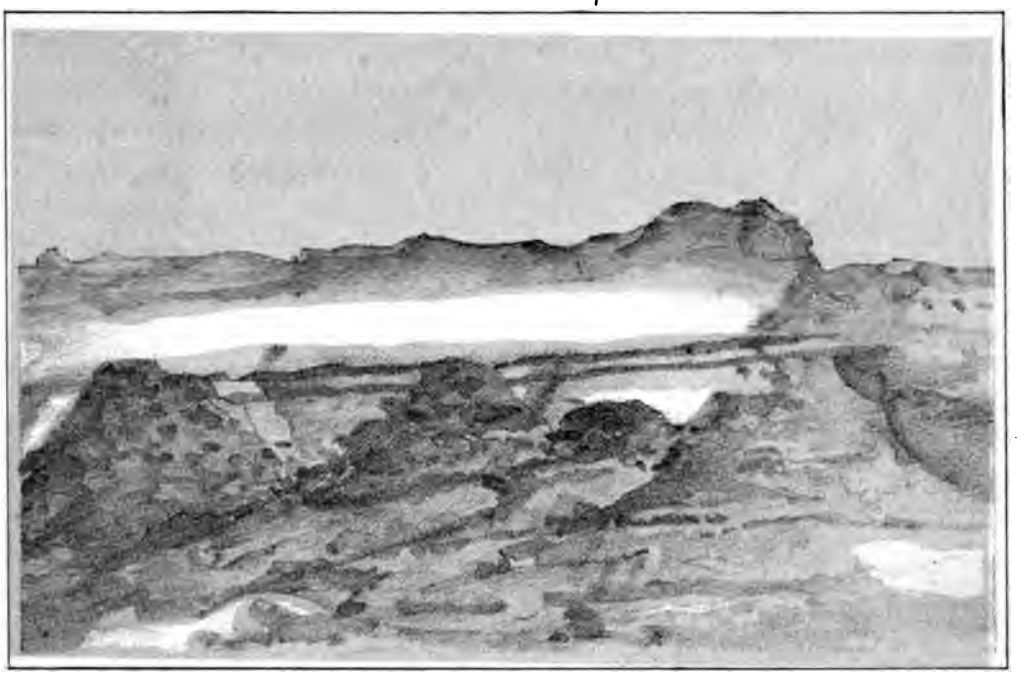
The islands of Jubal, Towilah, and the two Gaysooms, consist largely of soft white limestone strata, nearly horizontal, containing many fossils and shells. The fossils and shells of Jubal indicate that its underlying strata belong to the Upper Miocene series, and the overlying to the Pliocene period.

4. The Deposits of Diluvial Period. — At some points along the coast line, deposits are found belonging to the Diluvial period; at other points, the Upper Miocene rocks are uncovered down to the shore.

On the coast line, a mile or so from the northwesterly extremity of Gebel Zeit, the sea waves beat against a bed of indurated clay belonging to the Upper Miocene series.

Upon this clay rests a stratum, several feet in thickness, largely made up of a compact mass of Diluvial shells. On the seaward

Plate 27



side of Gebel Zeit, are also found at various points these Diluvial deposits consisting of coral limestone, limestone *detritus*, sands, and shells. They are also found, here and there, along the borders of the Gulfs of Gemsah and Zeit. Perhaps they once fringed the entire coast line, but, with time, have been more or less disintegrated and swept away.

As an instance of a geological force that has been active from the Diluvial down to the present time, I may cite the formation of coral reefs that are now being built up along nearly the entire sea line of the region explored.

As a conclusion to my geological notes, I append thereto a list of fossils and shells obtained, subdividing it in conformity to localities and geological periods. I have considered it necessary to give only generic names, adding thereto that of the species when recognised.

LIST OF FOSSILS AND SHELLS

I. — Great Plain.

1. *Cretaceous Period* (Upper Cretaceous Series).
   - Gryphæa (age uncertain).
   - Pecten (unknown species).

2. *Miocene Period* (Upper Miocene Series).
   - Artemis.
   - Bulla.
   - Cardita.
   - Cardium.

Conus.
Lithodomus.
Ostrea gigantea.
» crassissima.
» digitalina.
Placuna miocenica.

II. — Coast Plain.

1. Cretaceous Period (Upper Cretaceous Series).

No recognisable fossils or shells were found in the rocks of this series where exposed along the borders of the Watershed range.

2. Miocene Period (Upper Miocene Series).

Arca.
Artemis.
Bulla lignaria.
Cardium.
» Darwini.
Cassidarea.
Cerithium.
Chama.
Clypeaster (2 species).
Conus (2 species).
Corbis.
Cyprea.
Cytherea.
Diplodonta dilatata.
Ficula condita.
Lucina.

Ostrea gigantea.
» crassisima.
» Virleti.
Pecten.
Pectunculus.
» lividus.
Tapes.
» vetulus.
Venus.
Carodon megalodon.
Neliastræa Ellisi.

3. Diluvial Period.

Arca (2 species).
Artemis.
Cardium (2 species).
» levatum.
Cythera chione.
Ficula reticulata.
Lucina tigrana.
Mactra.
Meroe (2 species)
Pectunculus stellatus.

III. — Jifatin Islands.

1. Miocene Period (Upper Miocene Series).

Arca Noæ.
Cardium.
Clypeaster.
Conus.

Lucina tigrana.
Pecten (unknown species)
»
» Benedictus.
Pectunculus.
» stellatus.
Pinna.
Voluta ficulina.

IV. — Shadwan Island.

1. Miocene Period (Upper Miocene Series)

Cardium.
Cassis.
Conus (2 species).
Cytherea.
Euspatangus (?)
Lucina.
Pectunculus lividus.
Pinna.

2. Pliocene Period.

Avicula.
Margaritifera.
Cardium.
Cerithium.
Fundulus.
Lucina.
Venus.

V. — Jubal Island.

1. *Miocene Period* (Upper Miocene Series).

Artemis orbicularis.
Cardium.
Chama.
Clypeaster.
Pecten (unknown species).
» Benedictus.
» Malvina.
Pectunculus lividus.
Tapes.
Tellina lacunosa.

2. *Pliocene Period.*

Aspergillum.
Glycimeris.
Pecten.
Pectunculus.
Strombus.
Tapes.

THE PETROLEUM QUESTION

From the foregoing geological notes, necessarily desultory in their character, as a premise, may be drawn the conclusion that the sedimentary beds of the Great and Coast plains belong respectively to the same geological epochs and periods; in other words, that while the beds forming the Upper Cretaceous series of the Great plain were being deposited similar beds were, at the same time, being deposited in the region that I have denominated the Coast plain; and that while the Upper Miocene series of rocks were being deposited upon the Upper Cretaceous beds in the one locality, they were likewise being deposited upon similar beds in the other.

Moreover, in view of the relations which the different kinds of igneous and crystalline rocks of the Gebel Esh range bear to each other, and to the Cretaceous and Miocene sedimentary beds with which they are in contact, it is clear, that their intrusion, or, perhaps otherwise, their elevation above the sea, together with their superimposed sedimentary beds, must have occurred during several different geological periods, and that too, probably, for the most part, after the deposition of the Upper Miocene series. It appears, therefore, that in the Cretaceous and Miocene periods, signalized respectively, in this region, by the deposition of the Upper Cretaceous and Upper Miocene series, the two plains formed, during such depositions, parts of one and the same continuous sea-bottom.

The fact may also be noted here, that, in this region, the beds of the Eocene period, as also those of the Lower Miocene series are entirely wanting; the Upper Miocene beds resting directly on those of the Upper Cretaceous. It, is, therefore, to be inferred that, during the time that elapsed between the deposition of the Upper Cretaceous beds and those of the Upper Miocene series this area of territory stood above the level of the sea. This fact is more particularly worthy of note when it is borne in mind that less than fifty miles to the northward of Gebel Gharib near Zafarana, the Eocene rocks are largely developed, their beds resting in natural order of sequence directly upon the Upper Cretaceous strata. It thus appears, that while the region explored was elevated above the sea the country to the northward was depressed below it.

The unity of the Great and Coast plains having been established from a geological point of view, it naturally follows that any phenomena, secondary in character, observed in the one locality, may, other things equal, be looked for in the other; that is to say, if petroleum be found in the one plain it may naturally be expected in the other.

This consideration brings me to a review, or statement of facts with resulting inferences and conclusions, in reference to the question of petroleum.

At the commencement of my explorations, the only points where petroleum, or indications of it, were known to exist, were Gebel Zeit and Gemsah. The existence of free, or liquid petroleum, at the surface of the ground, close to the shore, and between it and the porphyry hills skirting the sea at Gebel Zeit, has been known, I might say, from time immemorial; the chain of hills itself having taken its name from the presence of the oil at its foot; the term Gebel Zeit signifying Oil Mountain. It is likewise the "*Mons Petrolius*" of the Romans, who made use of the oil in their industrial pursuits of quarrying and mining at various points in the mountains of the Watershed range. As

an instance of its use by them, I may cite a lamp of pottery-ware which I found buried in the sands in the midst of the ruins of an ancient mining camp in the region of the gold mines of Hammamat, situated in the Watershed range, midway between Keneh and Kosseir. This lamp had lain in the desert sands for over two thousand years. It contained, however, a quantity of petroleum dried down to the consistency of solid bitumen, which on being lighted, burned readily with a free, black, smoky flame. Niches, cut in the sides of the galleries of their subterranean workings, where their lamps were placed, together with the surfaces of the surrounding or overhanging rocks blackened with smoke, indicated plainly enough the use made by the Romans of this material for lighting up their mines.

It appears that, at Gemsah, petroleum, at about sea level, was first discovered some twenty years ago in mining for the sulphur with which, at that place, the gypsum deposits are accompanied. At the commencement of my reconnaissance, a well sunk at Gemsah, near the sea, had given for a short time a free flow of petroleum at depths, respectively, of about one hundred, and one hundred and twenty-five feet.

With the foregoing allusions to the only points where either petroleum or indications of it were known to exist, I will now give the result, in this regard, of my reconnaissance. To this end, I wil first note the discovery of —

I. — Rocks with Bituminous Infiltrations.

1st. — The plateau forming the southeasterly extremity of the Gebel Esh range, known as Gebel Abou Shaar, consists, as heretofore remarked of Upper Miocene limestone strata uplifted by the action of subterranean forces. One of these strata, near Bir Abou Shaar, resting at an angle of about 40 degrees on the

seaward side of the plateau, consists of a dark drab or brown-coloured limestone, of very uneven fracture, and exceedingly rough to the touch. The pores or interstices of this rock are filled with bituminous oils the elements of which could never have originated with the rock itself. It is evidently a case of bituminous impregnation brought on, apparently, by infiltration from petroleum deposits lying beneath. It will be remembered that the water of Bir Abou Shaar is more or less charged with sulphuretted hydrogen and that a large field of gypsum covers the plain immediately in front of the plateau and well at its edge. There appears, therefore, as regards the action of geological forces, to be a complete parallel between this point and Gemsah. Other strata of the limestone of the plateau likewise give proofs of bituminous impregnation, though not to so great an extent as the one just described.

2nd. — At the foot of Middle Saddle, in the Gebel Esh range, near the edge of the Coast plain, there are massive beds of limestone, gypsum, and clay, belonging to the Upper Miocene series.

The limestone is of a light buff colour, sometimes compact, somestimes cavernous, and in some parts semi-crystalline. In some places its strata have been dislocated and broken up in such a way, as to indicate that these phenomena are the result of subterranean forces acting under intense heat and pressure from below.

As regards the gypsum beds, it is quite natural to conclude that they are here, the result of chemical changes in limestone, similar to those which took place at Gemsah, heretofore noted.

A massive bed of highly indurated clay of a light drab colour, found in connection with the limestones and gypsum, is cut with irregular seams or joints, and presents in many places a mottled appearance, the result of dark-brown or black spots and patches upon its exposed surface. Examination shows that in connection with these discolourations, seen more particularly in conjunction with the seams or joints, there has taken place an impregnation or infiltration of bituminous oil.

3rd. — In my summary of the different kinds of beds that make up the rocks between Gebel and Ras Gharib, I referred to a stratum of calcareous sandstone of friable texture, and bluish or greenish grey tinge of colour; as also to a bed of smoky-grey limestone containing fossils or shells of the *Ostrea gigentis*. The bluish or greenish tinge of colour presented by the sandstone, as also the smoky hue of the limestone, is due to the fact that the interstices or pores of both of these rocks contain bituminous or oil substances. It is a noticeable fact, in regard to the limestone, that the *Ostrea gigantea* fossils or shells, in contradistinction to the smoky grey of the mass of the rock, have taken on, through the effect of the impregnation, a dark brown or brownish black colour.

4th. — For the sake more particularly of comparison, I may, here point out the fact, that fissure surfaces of semi-crystalline limestone taken from a pit or well sunk in the narrow-gorge near the sea between the twin summits of the Gemsah headland are discoloured with bituminous infiltrations, the result evidently of the volatilization or evaporation of petroleum having worked its way up along the cracks, seams, and fissures, caused by the upheaval of the strata heretofore referred to; while, at same time, the limestone itself gives clear evidence of containing hydro-carbon oils within its pores.

5th. — A case which is a perfect parallel to the preceding one, and upon which too great stress cannot be laid as a convincing proof of the presence of petroleum in the Great plain, is the discovery, by means of a trench dug at the foot of the Limestone chain in Wady Dhib, of fissure surfaces of a limestone stratum, likewise discoloured with bituminous infiltrations, the rock itself being impregnated with hydro-carbon oil. The petroleum already found at Gemsah, definitively proves itself to be the origin of the bituminous matter and impregnating oil at that place; so now, when it is borne in mind that the bituminous indications and oil impregnations discovered at Wady Dhib, in the Great plain, could

not have come from above, nor, on the other hand, originated from the rocks themselves, there remains only the conclusion that, as in the case at Gemsah, they must be the result of infiltration from a petroleum reservoir below.

6th. — As a final and perhaps noteworthy instance of bituminous impregnation discovered I now refer to the massive strata of light-grey friable sandstone, heretofore made note of as forming the lowest of the exposed beds of the Upper Cretaceous Series.

This sandstone, normally of a light-grey colour, is, in many places, mottled with dark or black spots; in others, the entire mass is black or brownish black. These phenomena were observed at many points along the entire length and breadth of the series, where exposed, from Bir El-Melaha to near Gebel Gharib. Tests have proved that where these discolourations occur, bituminous or oil infiltration has sometimes, to some extent, taken place. The origin of it may perhaps properly be referred to the cause or causes which, in the other cases just noted, have presumably produced similar results; namely petroleum or bituminous infiltrations from below.

With the foregoing summary of instances observed, of rocks showing bituminous indications, I will now refer particularly to —

II. — Rocks impregnated with Hydro-Carbon Oils and Gases.

A most interesting feature in this regard consists in the fact that the limestone and marl strata of what I have termed the Limestone chain in the Great plain, and Limestone hills in the Coast plain, belonging to the Upper Cretaceous series, are, apparently throughout their entire extent, to a greater or less degree permeated or impregnated with hydro-carbon oils and gases. These oils and gases are, so to speak, intimately combined with the texture of the rock, and give no direct physical indication of

their presence. It is only by means of decomposition on the one hand, or distillation on the other, that the fact of their existence in the pores of the rock becomes known. Likewise, among the limestones and calcareous sandstones of the Coast plain, belonging to the Upper Miocene series, there are many of the strata, between Abou Shaar and Ras Gharib, more or less permeated with hydro-carbon compounds. It may be that in isolated cases the elements of the oil contained in the interstices of these rocks originated with the rock itself, though, for the most part, there are convincing evidences of impregnation or infiltration from below. Proofs that the latter is, in general, the case, are especially observable in the strata of the Limestone chain and hills, where, for a distance of about forty-five miles, I had a good opportunity of noting the continuity of the impregnation or infiltration as also the fact that it is about the same in degree, and that, throughout the entire distance, it must have taken place under similar conditions.

It is, therefore, natural to conclude that, along this tilted chain of limestones and marls, the intrusion of the hydro-carbon oils and gases, as well as the infiltration in fissure surfaces of bituminous matter, occurred at one and the same time, and must have been the effect of one and the same cause. Of the various strata of which the chain is composed, the marls below appear to have absorbed the heavier hydro-carbons; the limestones above, the lighter; while the strata or layers of reddish-brown or drab-coloured limestone disks, and globes, heretofore described as forming a marked feature of the chain along its entire length, contain, in addition to the lighter oils, the hydro-carbon gases.

An examination of these strata, at Wadi Dhib, showed first below the fissure surfaces heretofore referred to blackened with infiltrations of bituminous mater; then above, a kind of sandy marl of a reddish-brown colour containing an oil that possesses the physical properties and gives the chemical reactions of a paraffin; while still higher, are limestone strata and layers of disks, interstratified

with each other and with layers of flint, permeated with the lighter hydro-carbon oils, and gases.

An examination of the relation of these layers of limestone disks to the proper limestone strata and to the flint layers, indicate the disks to have been formed from the limestone strata themselves; apparently, through their having been impregnated with hydro-carbons evolved under the required heat and pressure from below.

In addition to the detecting of bituminous matter and hydro-carbon oils and gases, I have in conclusion to cite that of —

III. — Volatile Petroleum.

This discovery took place at the extreme northeasterly end of Gebel Zeit, a distance of sixteen or seventeen miles from the petroleum well, and about a mile beyond the last outcrop of the granitic rock.

There are found at this place, as heretofore explained, massive strata of semi-crystalline limestone, as also a stratum of anhydrite, or water-free sulphate of lime.

These rocks are situated between a gypsum crest, which here forms the highest part of the ridge, and the sea. They are near to the latter, and, as before remarked, have been greatly tilted. Indeed the anhydrite has the appearance, so great is its inclination, of being a vein rather than a bed or stratum.

The limestone has a smoky tinge of colour and, on being forcibly struck with a hammer, gives off an unmistakable odour of petroleum.

The stratum of anhydrite is about three feet in thickness and was traced about a quarter of a mile in a direction parallel with the range of gypsum hills. The rock is of a dark-grey or

brownish-black colour, and, on being broken with a hammer or sledge, gives off a very strong odour of petroleum. An analysis of the anhydrite proves that it contains from four to five per cent of volatile petroleum. The discovery of this petroleum, filling the pores and interstices of the limestone and anhydrite, is most important for the elements of it could not have originated with the rocks themselves. Such being the case, there remains simply the conclusion that it can be the result only of an infiltration under heat and pressure, from a petroleum deposit lying, at some as yet unknown depth, below.

IV. — Extent of Petroleum Indications.

In view of what has thus far been said upon the petroleum question, it is clearly shown that petroleum indications, as well as petroleum itself, exist at various points in the regions explored; in one direction from Gebel Abou Shaar to the neighbourhood of Gebel and Ras Gharib; in the other, from the sea, to and beyond the Limestone chain in the Great plain; and when it is remembered that only a very small portion of the territory over which my reconnaissance extended could be minutely examined, it is safe to conclude that, had time permitted an exhaustive search, there would have been been discovered many more proofs of existing deposits of petroleum than those just enumerated.

Perhaps, however, as it is, discoveries enough were made to justify the conclusion that deposits must exist in many places within the territorial limits just described. The tract of country traversed from Gebel Abou Shaar to Abou Mingarh, although belonging, geologically, to the same periods as the country between Gebel Abou Shaar and Gebel and Ras Gharib, presented no indications of petroleum. This fact is, nevertheless, no proof that it does not exist in that region in the depths below; for, on the

one hand, there may exist intrusions of igneous rocks causing oil indications which were not discovered; and, on the other hand, there may have been no intrusions necessary to the fissuring of overlying strata so as to permit either petroleum, or its oils and gases, to reach the surface.

As regards the islands of Jifatin, the geological and mineralogical character of the rocks of which I have already described, it may be remarked that, although their limestones are geologically of the same age as those of Gebel Abou Shaar and Gemsah, and resemble them very much as regards their physical structure, and moreover, have without doubt been upheaved by subterranean forces, nevertheless no indications of petroleum were found upon them. If petroleum exist in any of the strata below, as geologically it may, it would probably be found only at a great depth. Under such conditions, these islands cannot be recommended as a suitable field for practical research.

If the islands of Jifatin are placed without the limits of practical research, still more is that of Shadwan, two-thirds of which consists of granitic rock, probably, as heretofore mentioned, of the same age as the crystalline rocks of the Watershed range.

The northwesterly part of the island consists of Pliocene and the latest Upper Miocene strata, with no indications whatever of petroleum. It may, therefore, be set down as lying beyond the limits of practical research.

The islands of Jubal, Towilah, North Gaysoom, and South Gaysoom, situated midway between Shadwan and Gebel Zeit, are composed of strata of the same geological age as those of the northwesterly part of Shadwan, namely, of the Pliocene period and of the latest of the Upper Miocene series. On these islands there are no signs, at all, of petroleum, which, if it exist in any of the formations below, is, in my opinion, likely to be beyond any practicable depth.

With the foregoing reference to the extent of territory within which petroleum indications, as also petroleum itself, have been

found, and allusions to those localities where practical researches would probably be of no avail, I now come to a consideration of —

V. — Causes of Petroleum Indications.

The remote cause consists in the intrusion of masses of crystalline rocks along the easterly border of the Watershed range, as also at various places in the Gebel Esh range; then again, in the intrusion of the porphyry and granite which form the Zeit Hills; and finally, in the presumed intrusion of igneous rock at Gemsah. On account of the intrusion or eruption of these crystalline rocks, already described, the sedimentary beds were tilted at different angles, giving rise in them to seams and fissures connecting the petroleum deposits below with the superior strata or surface of the ground above. As instances thereof, I will first refer to a fact already cited, namely, that in the Great plain, along the border of the Gebel Esh range, the strata of the Upper Cretaceous series dip about 12 degrees toward the southwest, while on the side of the plain, next to the Watershed, the dip, at one point, in front of Gebel Mongoul, amounts to about 75 degrees towards the the northeast.

The tilting of these beds, on opposite sides of the plain, towards each other, naturally caused a fracturing and fissuring of them along their synclinal axis. It was in or near this axis that bituminous matter, and oil and gas indications of petroleum, were discovered.

As a second instance, I will refer to Gebel Zeit and Ras Gemsah, where the eruption of porphyry, at the one place, and the presumed intrusion of igneous rock, at the other, fissured the sedimentary beds overlying the petroleum deposits near their contact with these rocks to such an extent as to afford opportunity for free petroleum, under pressure, to make its way up to the surface of the ground.

I have referred to the remote cause of petroleum and its indications at the surface of the ground and shown how, to this end, by means of this remote cause, the sedimentary beds overlying probable petroleum deposits, have been seamed and fissured. There remains only a reference to proximate causes, namely: in some cases, heat and pressure resulting from the eruption or intrusion of igneous rocks, by means of which volatile petroleum, oils, and gases, have been forced to the surface and impregnated the upperlying strata; in others, the pressure resulting from confined gases generated in connection with the petroleum deposits themselves. The volatile petroleum in the crystalline limestone and anhydrite at the northwesterly extremity of Gebel Zeit, the bituminous matter in the interstices of the various rocks cited from Abou Shaar to the neighbourhood of Gebel and Ras Gharib, and the oils and gases in the Limestone chain, are all, doubtless, effects of heat and pressure; while the presence of free or liquid petroleum at Gebel Zeit and Ras Gemsah near the surface of the ground is due to the pressure of gases generated and confined in connection with the petroleum below.

VI. — Source of the Petroleum.

In the region of country explored, no discoveries were made enabling me to determine the source of the petroleum the indications of which have been described, or, in other words, to fix the geological period in the rocks of which its deposits are to be found.

The lowest sedimentary beds found, were those of the Upper Cretaceous series. They are exposed along what I have termed the Limestone Chain and hills, and contain indications, already discussed of petroleum deposits that presumably lie in the strata of some period below.

I was, at the time of my reconnaissance, led to infer that the petroleum indications in the Great plain were the result of the partial distillation of coal beds lying underneath, and that the rocks of the plain, perhaps even those of the Cretaceous period itself, might be bedded directly upon them; those of the Jurassic, Triassic and Permian periods, which, in the natural order of sequence, as regards time, fall between the Cretaceous and Carboniferous periods, having all, or at least a part of them, never been deposited.

Information, however, subsequently received through the courtesy of Dr. G. Schweinfurth, who had previously made a geological reconnaissance through the regions of Wady Arabah, Wady Dakl, Gebel Zeit, etc., leads me to the conclusion that the above inference is incorrect, and that these indications are proofs rather, of petroleum, than coal, in the Great plain. This information also enables me to speak definitively as regards the geological formation or period in which the petroleum deposits may be presumed to exist.

Dr. Schweinfurth found the sandstone of the eastern slope of the Watershed range resting, with a thickness of about 300 feet, directly upon its crystalline rocks and discovered in Wady Arabah, not far from Zafarana, that the lowest division of the same belongs to the Devonian formation or period. Again, in Wady Dakl, a few miles to the south of St. Paul Convent, this sandstone, near its contact with porphyry, is interstratified with bituminous marl slate, formerly exploited by Figari Bey in search of coal, while behind the Watershed range, on the eastern slope of the nummulitic plateau, alternating marl and fossiliferous breccia beds, about 200 feet in thickness, forming there the lowest division of the Upper Cretaceous series, are superimposed directly upon the same sandstone, the lower strata of which, as above remarked, belong to the Divonian formation.

Resting upon these marls and breccias, Dr. Schweinfurth found the white chalk, — the uppermost strata of the Upper Cretaceous series, — containing fossils of *Ostrea vesicularis*, which,

near the sea, gives way to alternating layers of white chalk and flint concretions 200 feet in thickness. Then upon these is bedded Upper Miocene limestone containing fossils of the *Ostrea crassissima*, etc., which, in the hills, near the sea coast, is developed to a thickness of 300 feet.

Thus, from the discovery of Dr. Schweinfurth, it is seen that, along the continuation of the Coast plain, only about fifty miles northwesterly from Gebel and Ras Gharib, the points where, in that locality my reconnaissance terminated, the Devonian sandstone rests upon the crystalline rocks of the Watershed range, and that, behind this range, the strata of the Upper Cretaceous series rest upon this Devonian sandstone which is, itself, interstratified with marl-slate impregnated with bitumen. This bitumen is presumably an outcome from petroleum, which, in other places in the same formation, may form large deposits; as evidenced by its appearance at the surface on the sea coast at Gebel Zeit and Ras Gemsah.

Situated so near, and under conditions geologically similar, there can be only one conclusion as regards the region or country over which my researches extended; namely, that the Upper Cretaceous series of rocks rests, as in the locality referred to by Dr. Schweinfurth, directly upon the Devonian formation, and, therefore, that petroleum deposits in the Great and Coast plains, as for instance those at Gebel Zeit and Gemsah, may be found, as in the great petroleum region of Pennsylvania, in the rocks of the Devonian period.

The strata of the Upper Cretaceous series, bedded directly upon those of the Devonian period, prove that the rocks, not only of the Lower Cretaceous series, the Jurassic, Triassic and Permian periods, but also those of the Carboniferous period, failed to be deposited.

VII. — Places where to bore.

In so far as regards surface indications of petroleum, — after Gebel Zeit and Ras Gemsah, where borings have already been carried on for several months, — the most promising places in the Coast plain appear to me to be the vicinity of the north-westerly extremity of Gebel Zeit, where the crystalline limestone and anhydrite are impregnated with volatile petroleum, and the locality of Bir Abou Shaar, where the limestone strata of the plateau are impregnated with bituminous oils.

In the Great plain, the locality of Wady Dhib promises exceedingly well, as, at that place, the strata of the Limestone chain are impregnated with hydro-carbon oils and gases, and fissure surces in the same, show infiltrations of bituminous matter. The neighbourhood of Bir El-Melaha may also be named, as at this place there is a low geological level, while at the same time, the rocks show, as at Wady Dhib, oil and gas infiltrations.

In so far as depth is concerned, the most promising places to bore are, in my opinion, those just mentioned in the Great plain, where, on account of the tilting and wearing away on their edges of the beds of the Upper Cretaceous series, advantage can be taken of the lowest geological horizon or level. The most unfavourable are those in the Coast plain, where massive strata of the Upper Miocene series are bedded upon the Upper Cretaceous.

It having been clearly proved that the sources of the petroleum lie in the strata of the Devonian formation, it is evident that, granted sufficient surface indications, the lower down in the overlying strata that borings can begin the less it will be necessary to bore to reach the deposits; — for instance, at Gebel Zeit, Ras Gemsah, or any of the places named in the Coast plain, it

will be necessary to bore through the overlying strata of the Upper Miocene series and the entire series of the Upper Cretaceous rocks in order to reach the Devonian formation ; while at the lowest point in Wady Dhib, in the Great plain, near the petroleum indications referred to, as well as in the locality of Bir El-Melaha, one is, at the lowest point, about 500 feet down in the strata of the Upper Cretaceous series ; * hence, at these latter places, it would only be necessary to bore through the remaining lowest strata of the Upper Cretaceous series in order to reach the Devonian rocks.

Granted surface indications, a practical question, in reference to the selection of places where to bore, is their relative distance from the sea involving greater or less cost of transport, maintenance, etc., necessary to practical researches in the desert.

VIII. — Depths necessary to bore.

The depths necessary to bore, at the various points suggested in the Great and Coast plains, in order to arrive at the rocks of the Devonian formation and the probable petroleum deposits within them, cannot be determined with any definite degree of exactness.

Judging from the results of Dr. G. Schweinfurth's researches in the region of Wadys Arabah and Dakhl as regards the thickness, respectively, of the Upper Miocene and Upper Cretaceous beds, as also from my own examination of them in the country explored, I infer the minimum depth at which petroleum deposits may be reached in the Great plain, where boring can commence

* Indeed at one point, a short distance northwesterly from Wady Dhib, along the Limestone chain, the lowest geological horizon is about 700 feet down in the strata of the series.

at a geological horizon, or level, 500 feet down in the strata of the Upper Cretaceons series,* to be say 400 feet; while in the Coast plain I conclude it to be not less than 1,200 feet. On the other hand, as regards the maximum depth, I am of opinion that possibly 1,500 feet, even, may be required in the Great plain, and 2,000, or more, in the Coast plain.

I give these large figures as maximum depths in view of the fact that the beds forming a geological series are often very local and inconstant. They vary greatly as regards their degrees of development in different localities, and, as a rule, some of them are entirely wanting.

In view of these facts, it is evident that the thickness of a series at one place may not conform, at all, with its thickness at another.

In the Great plain it will be necessary, in order to arrive at a petroleum deposit, to bore through the strata that remain, — the lowest in the series, — of the Upper Cretaceous series, probably only a short distance, thence into the Devonian formation until the petroleum is reached, — an uncertain depth.

In the Coast plain it will be necessary to bore, first, through the strata of the Upper Miocene series, the minimum of which is at the most favourable points, say, 300 feet; thence, through the strata of the Upper Cretaceous series with a thickness, say, of from 800 to 1000 feet on to the Devonian rocks, thence, into these, — an uncertain depth.

It must not, however, be forgotten that, at the borings of Gebel Zeit and Gemsah, there is, at any time, the possibility of striking fissures in open communication with the petroleum deposits below, in which case nature would have performed, in her way, a part of the work necessary to be done. On the other hand,

* I may note the fact that a little northwesterly from Wady Dhib the Cretaceous strata have been worn down to a depth of about 700 feet.

owing to the nearness of the borings to porphyry at Gebel Zeit, there exists the danger of coming upon this rock.

As a conclusion to this question of depth, the remark is perhaps not out of place that, soon after the commencement of my reconnaissance and before my determination of the age of any of the geological formations, I felt convinced that no petroleum deposits would be found in the region at any shallow depth. I entertained this view from the fact that, at no points in the same, did there seem to be any indications whatever of free or liquid petroleum at the surface, except at Gebel Zeit and Gemsah, where the eruption of igneous rocks had presumably fissured the sedimentary beds. If the intrusion of igneous masses were necessary to the appearance of petroleum at the surface of the ground no other inference could be drawn than that the original deposits are at a considerable depth; and, finally, I may note the fact that in view of the result of my observations, the theory of Professor Fraas, of Stuttgart, to which publicity was given in the year 1864, namely, that the petroleum at Gemsah is due to the decomposition of animal bodies in the sea, and consequently quite superficial, rests, wholly, upon untenable ground.